Geology of the Mabou Highlands, Western Cape Breton Island, Nova Scotia

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ABSTRACT

The Mabou Highlands form an isolated massif located about 50 km southwest of the main Cape Breton Highlands. Foliated dioritic intrusive rocks form the eastern half of the Mabou Highlands and are surrounded by an injection gneiss complex consisting of quartzofeldspathic and amphibolitic gneisses and minor marble intruded by numerous sheets of diorite, porphyritic granodiorite, granite, syenogranite, aplite and pegmatite (in approximate intrusive sequence). Mylonitized leucotonalite forms the core of the western Mabou Highlands and is flanked by a variety of low to medium grade metamorphic rocks, including highly transposed quartz schist and phyllite, lithic metatuff, mafic schist and amphibolite, and interbanded mafic and felsic schist. Chemistry of the mafic metavolcanic rocks in the above metamorphic sequence indicates a tholeiitic composition and possible generation in an island-arc or back-arc environment. Geochemistry of the dioritic rocks and the leucotonalite suggest that they are cogenetic and derived from partial melting of metabasaltic (eclogite?) source rocks in a primitive volcanic-arc environment.

A major fault separates these inferred Late Hadrynian to early Paleozoic rocks from a belt of predominantly volcanic rocks of probable Silurian-Devonian age to the west. The latter include subgreenschist facies quartz-feldspar crystal tuff and lithic tuff with andesitic and basaltic flows and minor red siltstone and arenite. Chemical data suggest that the flow rocks are continental tholeiites. Locally fossiliferous inliers of shale, siltstone, quartz arenite and dolomitic limestone of Silurian(?) age occur in faulted contact with the volcanic rocks and as small inliers within Carboniferous sedimentary rocks to the west of the Highlands.

The Late Hadrynian to early Paleozoic metamorphic and intrusive rocks of the Mabou Highlands resemble those of the Cape Breton Highlands to the northeast in deformational and metamorphic history and in petrological and geochemical character. However, uncertainty remains as to the age(s) of these rock units.

Some potential exists for polymetallic sulphide deposits in the medasedimentary and metavolcanic schists of the western Mabou Highlands, and for barite deposits near the Horton-Windsor contact west of the Mabou Highlands.

INTRODUCTION

A diverse assemblage of igneous and metamorphic rocks underlies the high plateau commonly referred to as the Mabou Highlands in western Cape Breton Island. These complex rocks are separated from those of the Cape Breton Highlands to the northeast by a lowland underlain by Carboniferous rocks (Fig.

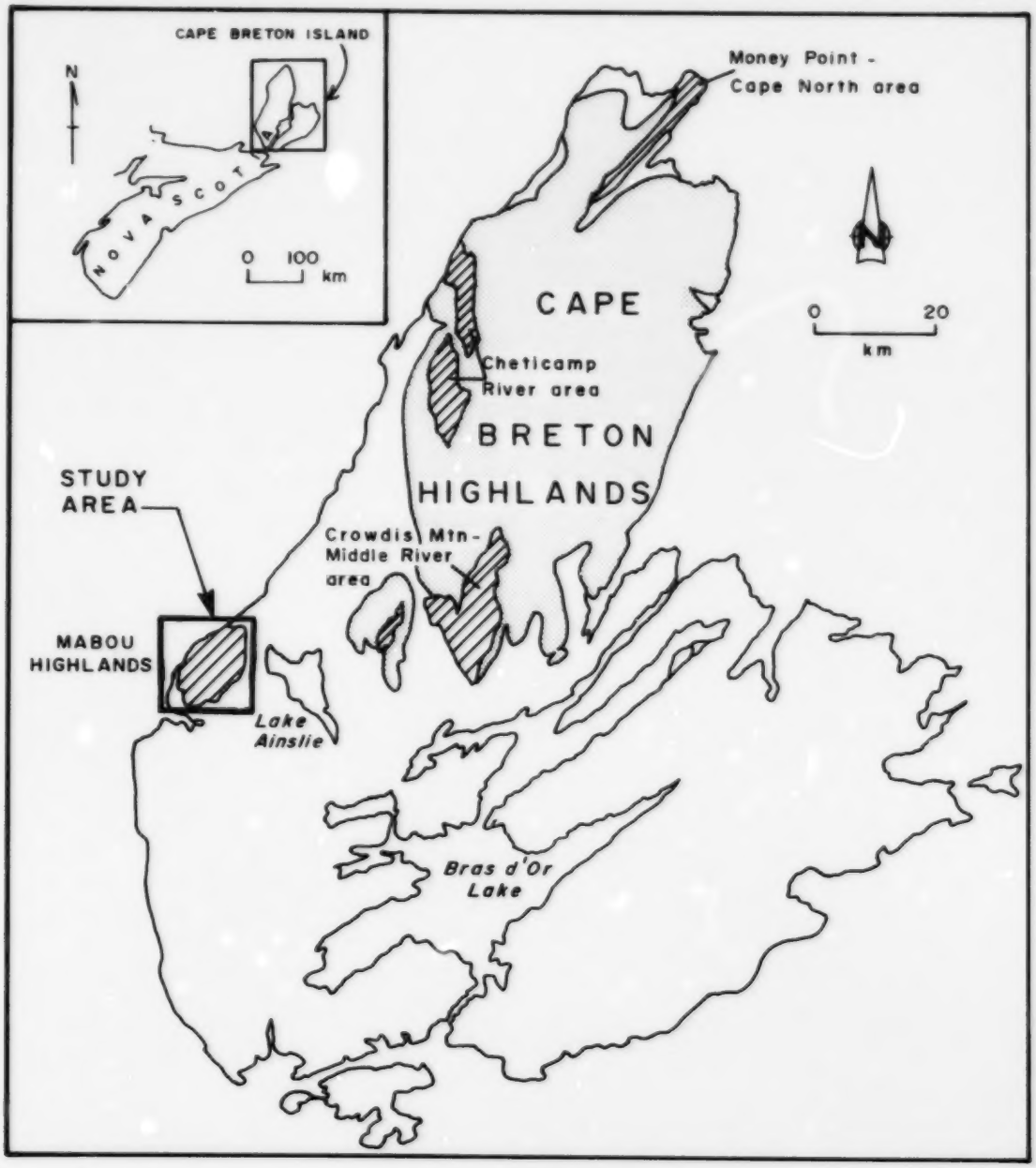


Figure 1. Outline map of Cape Breton Island showing location of the Mabou Highlands and metavolcanic and metasedimentary units (patterned areas) in the Cape Breton Highlands (shaded areas). Areas underlain mainly by Carboniferous sedimentary rocks surround the Highlands.

1). No systematic geological investigation of the Mabou Highlands had been done since the work of Norman (1933, 1935), Phinney (1956) and Wait (1959). The present study was undertaken to: (1) systematically remap the Mabou Highlands to better define the geology; (2) describe the petrography of metamorphic units, determine metamorphic grades and their distribution, and assess the conditions of metamorphism; (3) describe and interpret the petrography, geochemistry, and petrogenesis of igneous (and meta-igneous) units; (4) interpret the structural features of the Highlands and (5) make an assessment of economic potential.

The Mabou Highlands consist of an isolated flat plateau that borders the Gulf of St. Lawrence and has an approximate elevation of 350 m. The plateau is crudely elliptical and its long axis (approximately 15 km long) trends north-northeast, whereas the structural grain within the Highlands trends north. The Highlands rise steeply from the adjacent lowlands and form locally precipitous cliffs and headlands (notably Cape Mabou) along the Gulf of St. Lawrence to the northwest. Numerous youthful V-shaped river valleys dissect the plateau, creating a well developed radial drainage pattern. The area is densely forested except for large areas of cleared land on the plateau which are used as communal pasture.

The main highway (N.S. # 19) skirts the east side of the Mabou Highlands but a passable dirt road (the Mabou Highlands Road) crosses the plateau from Mabou Harbour northeast to Banks of Broad Cove and is joined by another dirt road from Glenora Falls to the east (map in pocket). A coastal road (partly paved) and hiking trails connect Banks of Broad Cove, Sight Point, Cape Mabou, and Mabou Mines. Although the Mabou Highlands are now largely uninhabited, numerous old trails and foundations attest to a considerable population earlier this century (Norman, 1935).

PREVIOUS WORK

The Carboniferous rocks peripheral to the Highlands were of primary interest to most early geological workers in the area (e.g. Fletcher, 1885; Douglas, 1944; Keating, 1949). The first geological map of the igneous and metamorphic rocks of the Mabou Highlands was by Norman (1933, 1935) as part of the Lake Ainslie map sheet. Norman subdivided the pre-Carboniferous rocks of the Mabou Highlands into three general units: a granodiorite-diorite unit with inclusions of quartzite and limestone, a sheared diorite unit and a unit of andesite, tuff and volcanic breccia. He called the latter unit the Mabou Highlands volcanic group and suggested a Paleozoic and(or) Precambrian age. The other two units were assigned to the Precambrian(?).

Phinney (1956) investigated structural features of the southwestern part of the Mabou Highlands, emphasizing the "volcanic group" of Norman (1935) and Carboniferous sedimentary rocks. He suggested that the volcanic group could be Siluro-Ordovician in age based on lithological similarities to the Arisaig section in the northern mainland of Nova Scotia and on the presence of two small isolated windows of fossiliferous Silurian quartzites and shales in conglomerate of the Horton Group west of the volcanic unit.

The most comprehensive study was by Wait (1959) who remapped the Mabou Highlands. He distinguished dolomitic marble, gneissic quartzite, muscovite schist and quartz-muscovite schist that he assigned to the George River Group of Bell and Goranson (1938) and recognized that some of these rocks occur as xenoliths in an extensive unit that he referred to as the Mabou Highlands complex. He suggested that this unit is Cambrian to Devonian and

described it, rather enigmatically, as "a complex of metamorphosed sediments(?) predominantly dioritic in composition". He noted that the complex is cut by syenite and aplite dykes and exhibits different intensities of deformation (crushing and shearing). He expressed uncertainty as to the igneous or metasedimentary origin of many of the rocks in the complex, but disagreed with Norman's (1935) interpretation that most of the rocks are igneous. Wait also described the inferred Siluro-Ordovician volcanic rocks, the isolated Silurian sedimentary exposures west of the Highlands noted by Phinney (1956) and adjacent Carboniferous units.

The petrology of the inferred Siluro-Ordovician volcanic rocks was investigated by Fox (1983) as a subproject of the present study, and it was concluded that they represent an intracontinental tholeiitic suite. Data from that study are included in this report.

The Mabou Highlands have been the focus of sporadic mineral exploration programs (e.g. Anaconda American Brass Limited, 1964; Coté, 1966; Newmont Mining Corporation, 1967; Hudgins, 1971). An assessment of the mineral potential of the area based on these and other reports was written by White (1978) who concluded: "The Mabou Highlands is an area of an abundance of geological unknowns. The geology map (Norman, 1933) is no longer considered reliable by companies and individuals who have worked in this area. Little work was ever done in a great portion of this region. In several cases assessments were made, good results and recommendations concluded but the work has never been followed up in detail."

METHODS

The pre-Carboniferous rocks of the Mabou Highlands were mapped by the authors in June, 1982. Orthophoto maps (scale 1:10,000) 11K/03-U1, -U2, -U3, -U4, -V3, -X1, -X2, -X4, -Y1 and -Y3 and 11K/06-S1 published by Land Registration and Information Services were used as base maps. Approximately 400 samples were collected, 150 of which were studied in thin section. Modal analyses of representative granitoid samples were done by the point counting of at least 200 grains using a binocular microscope on slabs stained for K-feldspar (Hutchison, 1974, p. 18).

A total of 52 samples (Appendices A and B) were selected from igneous rock units (Fig. 2) for chemical analyses. Major element analyses were completed by J. Cabilio in the Department of Geology, Acadia University, using the methods described in Appendix C. Trace element analyses were accomplished by atomic absorption spectrometry, X-ray fluorescence and other methods and mineral analyses were done by electron microprobe at Dalhousie University and University of Endinburgh (Appendix C).

A detailed geological map, including field data and sample locations, is included with this report (in pocket). A simplified version of this map is shown in Figure 2.

MAP UNITS - OVERVIEW

Metamorphic rocks of the Mabou Highlands are subdivided into five map units (map in pocket and Fig. 2), four of which are metasedimentary and metavolcanic schistose units of low to medium metamorphic grade, whereas the fifth consists largely of higher grade gneissic rocks extensively injected by a variety of granitoid sheets. The age of these units is not certain. Rb-Sr dating of metarhyolites from the banded schist unit indicate a late Precambrian age, but the data are not definitive (Gaudette et al., 1985). In this report, these units are considered to be late Precambrian to early Paleozoic.

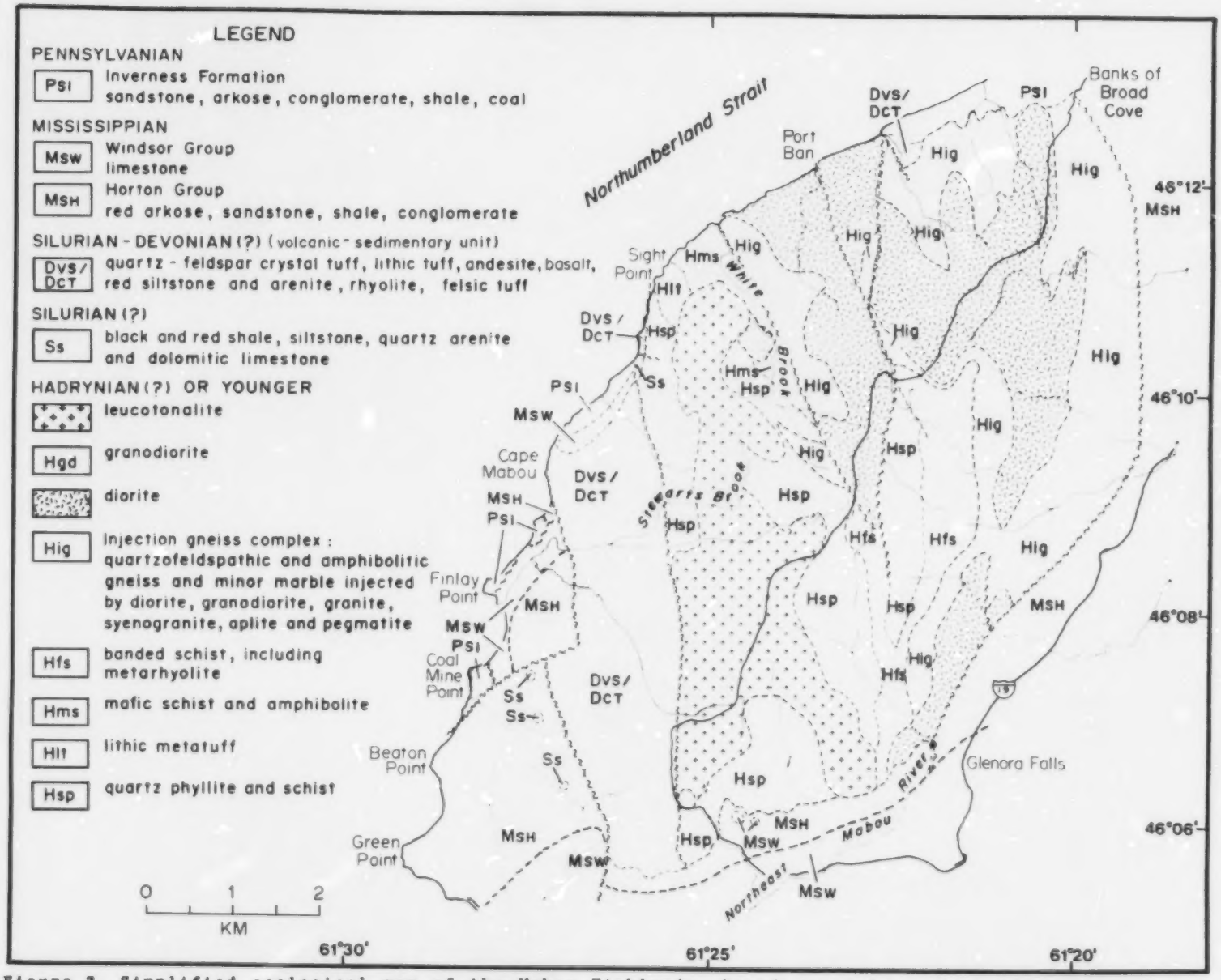


Figure 2. Simplified geological map of the Mabou Highlands, based on geology map in pocket.

These metamorphic rocks were intruded by large plutonic bodies of leucotonalite and diorite (Fig. 2). The former intruded the lower grade schists in the west and the latter intruded the higher grade gneisses in the east. The ages of these plutonic units are not certain, but they could be as young as Devonian (discussed in a subsequent section). Previous maps of the area (Norman, 1933, 1935; Wait, 1959) did not clearly distinguish between these plutonic units and the host metamorphic units.

The windows of sedimentary rock (Fig. 2) west of the map area, which were reported by Phinney (1956) to contain Silurian fossils, were sampled as part of this study but no macro- or microfossils were found. The fossil locality described by Phinney has been covered by recent road construction. A small fault-bounded area of lithologically similar sedimentary rocks southwest of Sight Point is also assigned to this unit.

The inferred Siluro-Ordovician Mabou Highlands volcanic group of Norman (1935) was remapped during the present study and is referred to informally as the Mabou volcanic-sedimentary unit (Fig. 2). It occurs on the western side of the map area, in faulted contact with the almost certainly older metamorphic and plutonic units. A small area of possibly correlative, mainly felsic volcanic rocks occurs in the northern part of the map area east of Port Ban (Fig. 2). These rocks are assigned tentatively to the Silurian-Devonian.

Flanking the Highlands and forming the lowland areas around them are Carboniferous rocks, mainly red clastic rocks of the Horton Group, locally overlain by limestone of the Windsor Group and by Pennsylvanian clastic rocks and coals of the Inverness Formation. These units were mapped previously by Norman (1933) and are not included in the present study.

The field relations and petrologic characteristics of the pre-Carboniferous rock units are discussed in the following sections.

METAMORPHIC UNITS

QUARTZ PHYLLITE AND SCHIST

Quartz phyllite and schist form the most extensive metamorphic unit of the western Mabou Highlands. The unit is exposed in two bands, a wide western band which is intruded by the leucotonalite pluton, and a much narrower eastern band (Fig. 2). Good sections are exposed in tributaries of the Northeast Mabou River northwest of Glenora Falls.

Typically, these rocks consist of finely laminated grey-green chloritic phyllite and grey quartz schist. They have well developed platy foliation that is commonly folded into upright subangular folds (F_2) and extensively kinked (F_3). Subordinate rock types include thin green calcite- chlorite-epidote phyllitic schists and thick blue-grey slaty phyllites. Toward the east the schists become porphyroblastic, typically with staurolite and(or) garnet.

Along its western margin the unit is in faulted contact with the Mabou volcanic-sedimentary unit, whereas to the east it is either in relatively sharp contact with metavolcanic units (in the north) or in gradational contact with the banded schist unit (in the south).

In thin section, the rocks of this unit are fine grained and strongly foliated (S_1) with common rootless, tight microfolds. Typically they contain quartz, muscovite, chlorite and biotite. Epidote and calcite are present in various amounts. Porphyroclastic textures are common, involving plagioclase, quartz (generally recrystallized) and rare volcanic fragments. The protolith of

this metasedimentary unit had a tuffaceous component and may have been greywacke. With increasing metamorphic grade toward the east, porphyroblasts of staurolite and garnet (or rarely chloritoid) overgrow the S_1 foliation and contrast strongly with relict porphyroclasts.

LITHIC METATUFF

Lithic metatuffs form a restricted unit which is well exposed at Sight Point (Fig. 2) and extends south-southeast 0.5 km where it is truncated by the leucotonalite pluton. The unit was not observed on the south-southeast side of the pluton so it is presumed to wedge out in this direction; whether for stratigraphic or structural reasons is unknown. The unit has a maximum possible thickness of about 300 m, assuming no internal repetition due to folding.

Typically, the rocks are grey-green schists containing cobble sized lithic fragments, which are greatly stretched and plunge steeply within the strongly developed platy foliation. The lithic fragments are predominantly intermediate volcanic lapilli with less abundant white felsic (pumice?) fragments. Interlayered with the lithic metatuff is blue-grey and green fine grained phyllitic schist which may represent ash and(or) fine grained tuff layers.

MAFIC SCHIST AND AMPHIBOLITE

The mafic schist and amphibolite unit is best exposed on the coast northeast of Sight Point and in Stewart Brook about 1 km east of Sight Point (Fig. 2). Together with various subordinate rock types, mafic schist and amphibole form a unit with an exposed maximum possible thickness of about 500 m. The unit is apparently faulted out to the southeast against injection gneiss and diorite. Amphibolite layers within the injection gneiss may represent related higher grade material.

The mafic schists are generally fine grained dark grey-green to green and contain hornblende, biotite and(or) chlorite, plagioclase, epidote and quartz. Some are compositionally uniform over large distances (e.g. in the middle section of Stewarts Brook) and probably represent basaltic flow sequences. However, many are inhomogeneous and are commonly interlayered with more intermediate grey quartzofeldspathic biotite schists and rare graphitic-sulphidic blue-black phyllitic schists, presumably representing various volcano-sedimentary components. Some of these inhomogeneous mafic-intermediate schists also contain crystal fragments and small lapilli and so are volcaniclastic or epiclastic in origin like the adjacent coarse grained lithic metatuff unit.

The associated amphibolites, up to tens of metres thick, are generally concordant with the enclosing mafic schists. These were probably original gabbroic sills which intruded the volcanic sequence. In general, the amphibolites are medium grained, dark green, relatively massive and consist of amphibole, biotite, plagioclase, quartz, sphene, pyrite and magnetite.

BANDED SCHIST

Banded schists form a distinctive unit, 500-600 m thick, in the central part of the Highlands. The unit is apparently repeated by folding and may extend farther east as part of the injection gneiss complex.

The unit consists of distinctive, compositionally varied schists, banded or layered on a centimetre to metre scale. The layers range from dark green amphibolitic schist through grey-green chloritic schist and

phyllite to pink and brown quartzofeldspathic (rhyolitic?) schist.

The contacts with the adjacent quartz schist unit in the southern part of the area are gradational; the banded schist becomes interlayered with laminated quartz-chlorite schist and rare garnet-mica schist. Toward the east, the schist grades imperceptibly into the injection gneiss complex by coarsening of grain size, increase in metamorphic grade and injection of granitoid sheets.

In thin section, the schists are fine- to medium-grained, of intermediate composition and consist mainly of quartz, altered feldspar, chlorite, biotite, muscovite, epidote, opaque phases and rare porphyroblasts of staurolite and(or) garnet.

The felsic layers, generally 1.5 to 4 m thick (rarely up to 20 m thick), are rhyolitic in composition and consist mainly of quartz and feldspar with less abundant muscovite and biotite and rare garnet. Mafic layers, less common and thinner than the felsic layers, consist of plagioclase, quartz, blue-green hornblende, biotite, opaque mineral(s) and apatite. It is probable that the thin felsic and mafic layers represent fine grained tuffs rather than flows.

INJECTION GNEISS COMPLEX

The injection gneiss complex in the eastern half of the Mabou Highlands forms an envelope up to 1 km wide which surrounds three large diorite bodies. In the complex, a variety of gneisses, amphibolites and mafic schists are extensively injected by sheets of diorite, porphyritic granodiorite, granite, syenogranite, aplite and minor pegmatite.

The mainly banded quartzo-feldspathic to amphibolitic gneisses, have local layers of coarse grained massive amphibolite and fine grained amphibolitic schist. Contacts with the schistose units to the west, although in part faulted, are clearly gradational. Thus, the gneisses are considered to be higher grade, granitoid-injected equivalents of those schistose units.

In thin section the gneisses are typically medium grained, thinly layered and display textures ranging from granoblastic to cataclastic. The amphibolitic gneisses and amphibolites consist mainly of hornblende (some have two generations of amphibole: hornblende and cummingtonite), plagioclase (An $_{27-45}$) and quartz, biotite altered to chlorite and epidote, with accessory opaque phase(s), sphene and apatite. More felsic layers and quartzofeldspathic sequences within the amphibolitic gneisses contain more quartz, K-feldspar and plagioclase and corresponding lesser amounts of hornblende and biotite (with associated secondary chlorite).

At several localities in the White Brook drainage system 1 km east of Port Ban, marble occurs within the injection gneiss sequence as one or more layers or lenses at least 6 m thick. Extensive faulting in this area makes correlation difficult. Typically the marble is white to grey, medium grained and granoblastic, and has local impure calc-silicate bands and occurrences of disseminated pyrite. No quartzite was observed in association with the marble, however, rhyolite occurs to the east of the marble, separated from the older rocks by faulting, and it is assumed that earlier references to quartzite in this area (e.g. Wait, 1956) may have referred to the rhyolite. As the inferred association of marble and quartzite was used to correlate these rocks with the George River Group of central Cape Breton Island (Wait, 1956), this lithological correlation is no longer considered valid.

GEOCHEMISTRY AND TECTONIC SIGNIFICANCE OF THE METAVOLCANIC ROCKS

Chemically analyzed samples (Table 1) include representative mafic schists from the mafic schist and amphibolite unit, amphibolite from the injection gneiss complex, and felsic (rhyolitic) schists from the banded schist unit. To a large extent these rocks have all been reconstituted texturally and mineralogically and loss-on-ignition values are up to 6%. However, the rocks appear to retain igneous chemical characteristics, as shown for example by a plot of mobile elements (Na_2O + K_2O) vs. $K_2O/(Na_2O + K_2O)$ (Hughes, 1972) on which most of the samples plot within the normal "igneous spectrum" (Fig. 3a).

Silica values (Table 1) range more or less continuously from 46% to 72% (48% to 73%, recalculated on a volatile-free basis) and although the number of samples is small, the values do not appear to represent a bimodal suite, an observation supported by field evidence. The mafic rocks are basaltic to andesitic in composition, and the felsic rocks are mainly dacitic and rhyodacitic (Fig. 3b).

Low Nb/Y ratios (0.26 $\pm$ 0.11) indicate that all these rocks are subalkaline (Fig. 3b). Total FeO values for the mafic schists are relatively high (Fig. 3c), suggesting that they may be tholeiitic rather than calc-alkalic. Abundances of the relatively immobile elements Ti, Zr, Y and Nb indicate that the mafic rocks were not formed in a within-plate environment; most samples plot in or close to the overlapping fields for island-arc basalts and ocean-floor basalts (Figs. 3d and 3e).

Relative abundances of Ti, Cr and Ni further suggest that the mafic rocks are transitional between island-arc tholeiites and ocean-floor basalts. On Ti vs. Cr and Ti/Cr vs. Ni plots (Figs. 3f and 3g) the samples straddle the boundary between these two basalt types, although the majority plot in the field of island-arc tholeiites. However, their Ti/V ratios (20-50) are more typical of ocean-floor or back-arc basalts than of island-arc tholeiites (Fig. 3h).

The tentative conclusion from the geochemical data is that the volcanic rocks probably formed in an island-arc environment rather than an ocean-floor environment. Field evidence supports this interpretation by not providing any of the typical indications of the latter environment, such as pillow basalts, dyke swarms, or ultramafic rocks. The transitional chemical character toward ocean-floor setting, if not an artifact of alteration, may reflect a component of spreading in an intra-arc environment.

PLUTONIC UNITS

DIORITE

Field Relations and Petrography

Three large lobate bodies of diorite underlie approximately half of the eastern Mabou Highlands (Fig. 2). An additional small stock-like body occurs in the north-central Highlands. The large bodies intruded the heterogeneous injection gneiss complex which contains many diorite sheets. The small body intruded metavolcanic rocks and may be in contact with the leucotonalite intrusion, although contact relations were not observed.

The age of the diorite is not certain. Hornblendes from five samples (1020, 1027, 1038, 1039 and 1077) yielded K-Ar ages of 356-370 Ma (A. Hayatsu, written communication, 1984). These ages may reflect a widespread Devonian thermal overprint which is recognized in parts of the Cape Breton

Table 1. Major and trace element analysis of metavolcanic rocks and amphibolite.

	Mafic Schists								Felsic Schists					Amphibolite
Sample	1703	1619	1094	1708	1704	1617	1035	1700	1574	1618	1702	1706	1705	1616
SiO_2	45.80	47.24	48.70	51.65	52.30	52.87	52.95	55.20	60.40	65.10	67.20	68.40	71.70	47.99
TiO_2	1.40	2.18	0.77	1.22	1.30	1.33	1.36	1.70	0.76	0.47	0.39	0.40	0.42	2.92
Al_2O_3	14.20	16.51	17.21	16.77	15.30	16.22	16.15	14.30	16.07	16.90	16.50	15.10	14.50	12.74
$Fe_2O_3^T$	12.80	12.72	9.89	9.61	9.20	11.89	12.06	11.29	6.80	3.56	1.98	2.67	2.53	15.29
MnO	0.20	0.20	0.13	0.17	0.17	0.26	0.30	0.23	0.08	0.06	0.04	0.05	0.05	0.37
MgO	9.9	6.34	7.72	5.26	3.60	4.58	3.82	3.10	2.65	1.40	1.00	1.10	0.54	7.62
CaO	6.40	7.97	5.33	7.20	6.70	6.74	7.14	5.20	4.53	3.50	2.20	2.30	1.20	8.54
Na_2O	2.60	3.03	3.82	3.54	3.50	2.98	3.11	3.40	3.35	5.60	4.80	5.60	5.70	2.85
K_2O	0.41	0.90	1.43	0.40	1.50	0.46	0.33	1.30	2.74	0.92	2.20	1.20	1.20	0.39
P_2O_5	0.53	0.45	0.38	0.20	0.34	0.17	0.11	0.45	0.20	0.14	0.13	0.12	0.08	0.22
LOI	5.70	2.61	4.17	3.65	6.10	1.68	2.02	3.50	1.50	1.90	2.90	2.70	1.00	1.14
Total	99.80	100.15	99.55	99.67	100.01	99.18	99.35	99.67	99.08	99.55	99.34	99.64	98.92	100.07
Trace elements (ppm)														
Ba	173	350	--	267	591	186	196	699	571	230	223	403	1989	--
Rb	7	16	36	6	20	10	6	21	79	14	32	15	16	20
Sr	347	443	--	377	405	432	387	339	387	290	148	152	255	--
Zr	127	191	205	89	160	97	114	167	209	86	95	79	189	210
Y	25	34	32	22	33	28	32	40	38	10	7	9	18	58
Nb	8	8	10	4	6	5	4	7	8	3	4	3	6	10
Pb	42	162	0	10	9	11	10	18	19	193	8	18	22	21
Zn	216	221	91	125	130	114	129	143	149	299	44	87	57	173
Cu	49	25	30	--	7	123	--	57	37	--	29	16	12	72
Ni	173	49	89	58	32	28	16	10	16	9	3	15	3	43
V	245	320	--	349	310	432	319	318	95	56	53	41	28	--
Cr	463	101	75	166	63	68	42	16	45	42	36	48	27	45
Th	2	4	--	3	2	1	2	6	6	2	1	2	3	--
Ga	16	19	--	21	17	20	21	20	15	16	18	15	17	--

$Fe_2O_3^T$ = total iron expressed as Fe_2O_3.

Highlands (e.g. Barr and Raeside, 1986) and they are unlikely to reflect the age of crystallization of the diorite. Dykes of most of the minor intrusive lithologies in the map area occur in the diorite. However, the relationship of the diorite to the other major intrusive unit, the leucotonalite, is not known because the two were not seen in contact. The injection gneiss

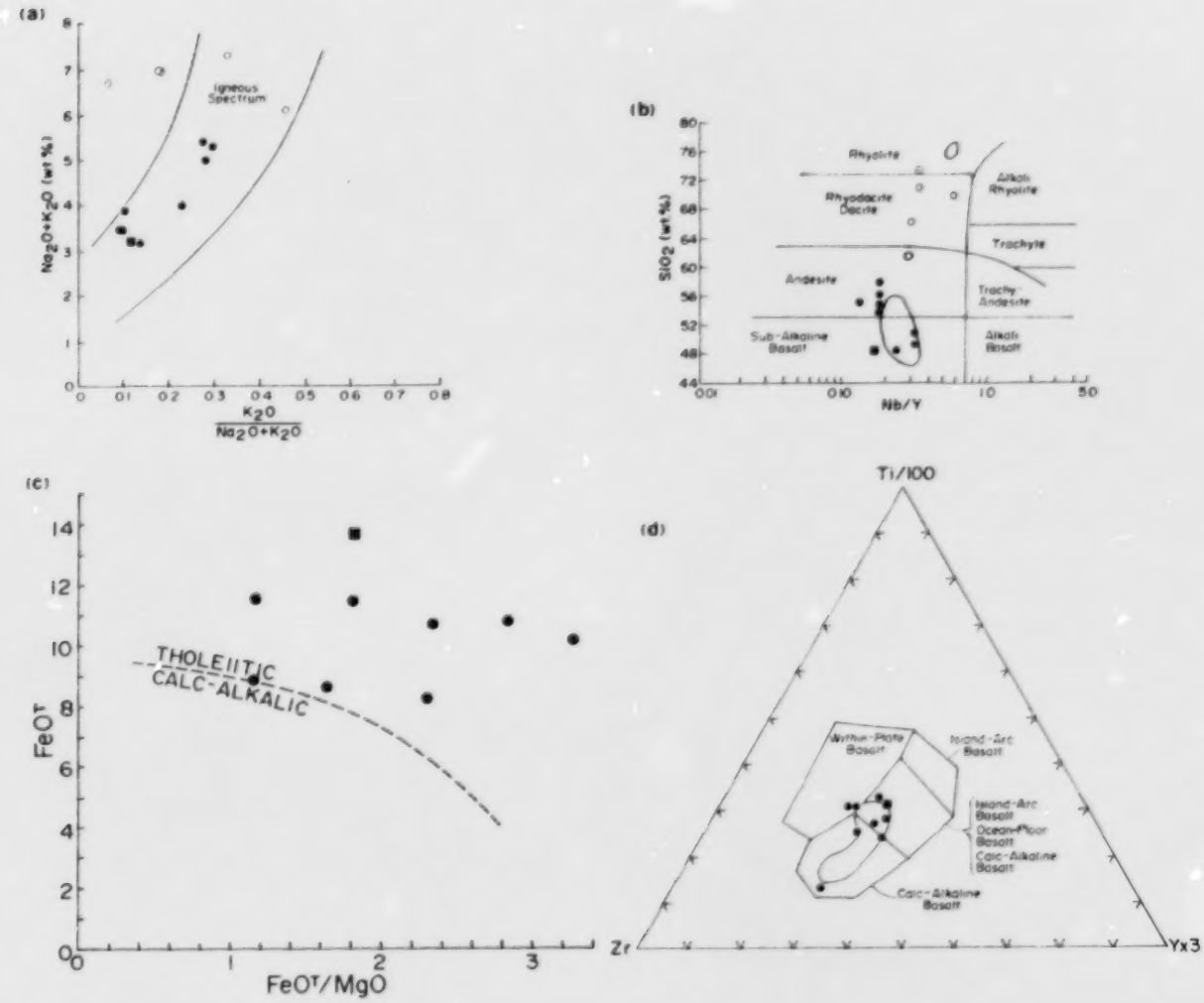
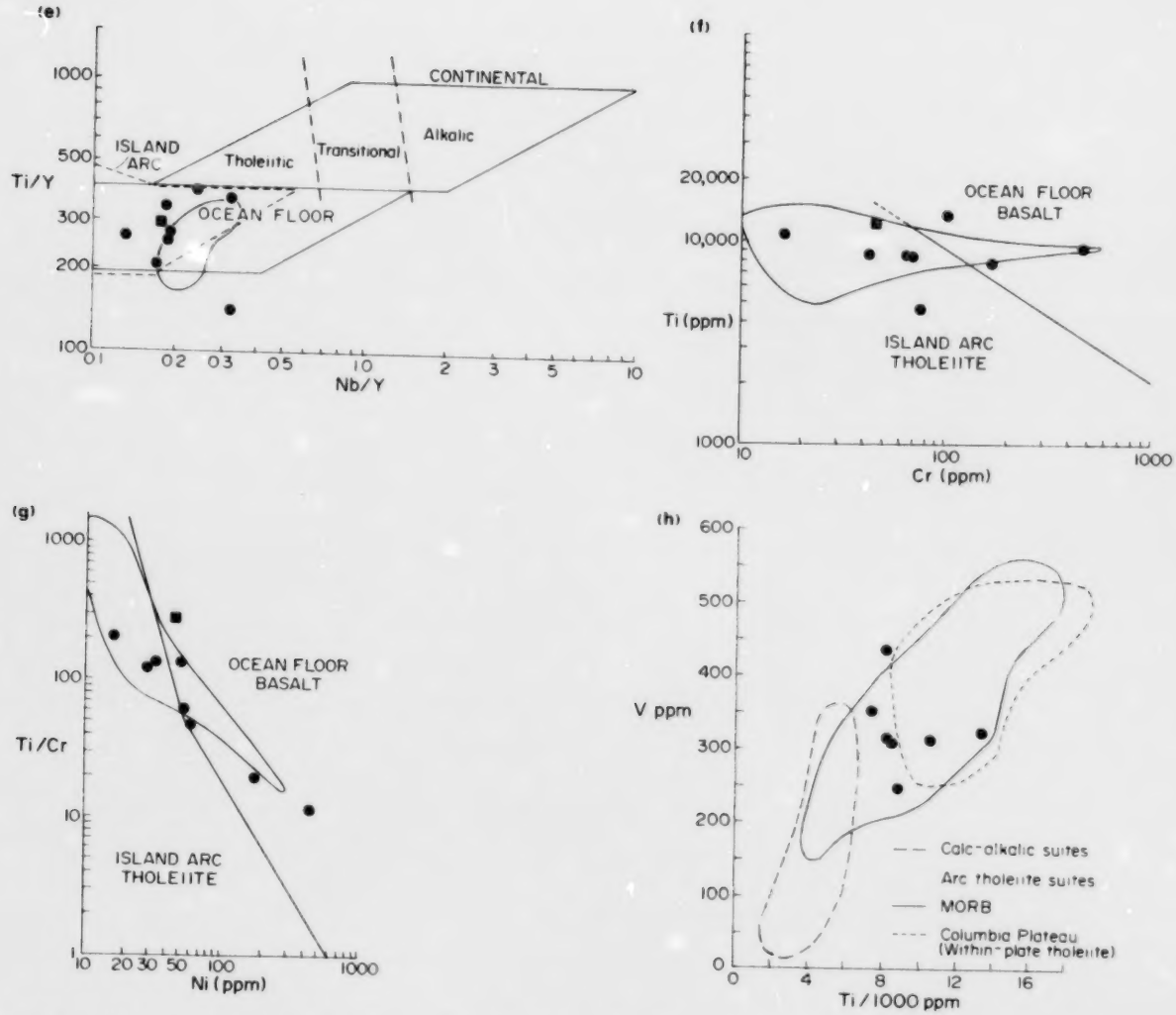


Figure 3. Geochemical discrimination diagrams for metavolcanic rocks. Closed circle, mafic schist (n=8); closed square, amphibolite (n=1); open circle, felsic rock (n=5). Circled field on some diagrams show compositional range of Honey Point metavolcanic rocks for comparison (unpublished data).

(a) $Na_2O + K_2O$ vs. $K_2O/(Na_2O+K_2O)$ diagram (after Hughes, 1972);
(b) SiO_2 vs. Nb/Y diagram (after Winchester and Floyd, 1977);
(c) FeO^T vs. FeO^T/MgO diagram (after Miyashiro, 1974);
(d) Zr-Ti-Y diagram (after Pearce and Cann, 1973);
(e) Ti/Y vs. Nb/Y diagram (after Pearce, 1982) (over);
(f) Ti vs. Cr diagram (after Pearce, 1975) (over);
(g) Ti/Cr vs. Ni diagram (after Beccaluva et al., 1979) (over);
(h) V vs. Ti diagram (after Shervais, 1982) (over).



complex appears to envelope the main diorite bodies, except where faults juxtapose diorite against other metamorphic units. Thus, the gneiss complex may represent a metamorphic aureole. However, amphibolitic and gneissic inclusions within the diorite have rotated foliations which suggest they were metamorphosed prior to intrusion by the diorite.

The diorite ranges in composition from diorite to quartz diorite according to the modal mineralogical classification of Streckeisen (1976). It is typically medium- to coarse-grained and mesocratic, dark green to black and white. All of the diorite bodies are variably deformed and commonly have a pervasive northerly foliation interpreted to be related to the D_2 deformational event (see section on Structural Geology) and localized shear zones of various orientations.

In thin section, the diorite is characterized by altered subhedral plagioclase, green amphibole (variably altered), biotite, interstitial quartz (generally < 5%), and accessory pyrite, magnetite, sphene, apatite and zircon. Alteration products include carbonate, chlorite, sphene and opaque phases. The primary texture is medium- to coarse-grained allotriomorphic-granular but in many samples deformation has

produced plagioclase and amphibole augen within a matrix of bent micas, granulated/strained quartz and secondary minerals.

Electron microprobe analyses show that plagioclase compositions (Table 2) fall in the range An_{21-41} but most are close to An_{25} (oligoclase), with smaller grains and rims tending to be more sodic. The amphiboles are magnesio-hornblendes (terminology of Leake, 1978) with Mg>Fe and TiO_2 about 1.5% (Table 3). Biotites show little zoning and generally have Mg>Fe and TiO_2 about 4% (Table 4).

Geochemistry

Silica values in the diorites range from 49-57% (Table 5) with the higher values in samples of strongly foliated "gneissic" diorite from the coastal section and dioritic sheets in the injection complex. Hence, in terms of SiO_2 content, the diorite is mafic to intermediate in composition. TiO_2 values are high (1.5-2%) as reflected by the relatively high Ti contents of biotite and amphibole in the diorite (Tables 3 and 4), and especially by the relative abundance of modal sphene. Al_2O_3 values are generally close to 16% (Table 5) and show little correlation with SiO_2 values (Fig. 4). Total iron as $Fe_2O_3{}^T$ (7-11%) and CaO (4.5-7.5%) show good negative correlation with SiO_2. TiO_2, MnO, and MgO also correlate negatively with SiO_2 but less well than $Fe_2O_3{}^T$ (Fig. 4). Irregularities in these trends and those of other elements may be related to crystal accumulation or separation. Na_2O values are somewhat high (3-6%) and correspond with the different plagioclase compositions (oligoclase-andesine) in the diorite. K_2O values are uniformly about 2%, somewhat high for diorites but consistent with the abundance of biotite in these rocks. P_2O_5 values are high (0.3-1%) and correlate with the range of modal abundance of apatite. They show a weak negative correlation with SiO_2 (Fig. 4) but also moderately good positive correlation with TiO_2, related to covariance of modal apatite and sphene abundance in the diorite.

Ba and Sr values cover a much greater range than Rb values which are generally low and uniform (about 40 ppm) (Fig. 5). Cu, Pb and Zn display some scatter, and Cu and Zn show weak negative correlation with SiO_2. Sulphur values (Table 5) span a wide range, reflected in the modal occurrence of pyrite in different amounts. Fluorine values are mainly between about 600 and 900 ppm, normal values in diorite. The other trace elements (Li, Be, Mo, Sn, W, U, Th, B and Bi) are all present in low concentrations and no particular patterns are apparent.

The diorite samples all plot in the calc-alkalic field on an AFM diagram (Fig. 6). Because of the relatively high potassium contents, their normative mineralogies plot in the monzodiorite or quartz monzodiorite fields (Fig. 7).

Three diorite samples were analyzed for rare earth elements (REE) (Table 6). All show similar chondrite-normalized patterns (Fig. 8), with light-enrichment, nearly linear trends and no europium anomalies. The sample with the lowest SiO_2 content has the lowest content of light REE, a commonly observed pattern consistent with a fractional crystallization model for petrogenesis, or variable amounts of partial melting (e.g. Hanson, 1980). The REE pattern is similar to that indicated by Hanson (1980) for melting of a basalt leaving an eclogite residue, rather than amphibolitic or granulitic residues which produce concave upwards or flat, heavy REE patterns, respectively.

Table 2. Representative electron microprobe analyses of plagioclase from plutonic units

	Diorite								Leucotonalite		Granodiorite		Granite
sample	1038		1077		1527		1582	1007	1128	1129	1500	1615	1602
	Core	Rim											
SiO_2	60.24	61.97	60.16	61.51	57.46	62.69	61.82	62.17	55.01	57.97	62.95	63.57	64.97
Al_2O_3	24.17	22.99	24.0	23.90	26.13	22.78	22.86	23.59	26.06	25.34	22.62	22.53	21.90
FeO(T)	0.10	0.19	0.16	0.18	0.22	0.20	0.13	0.18	0.16	0.25	0.16	0.09	0.11
CaO	5.72	4.41	5.56	5.51	8.38	4.38	4.23	5.09	7.68	7.79	4.35	4.02	2.93
Na_2O	8.29	9.03	8.06	8.31	6.70	8.91	8.85	8.46	7.13	6.99	8.98	9.42	9.99
K_2O	0.17	0.16	0.45	0.34	0.25	0.45	0.67	0.47	0.15	0.14	0.68	0.20	0.13
Total	98.69	98.75	98.69	99.75	99.14	99.39	98.56	99.97	96.20	98.48	99.74	99.84	100.02
Number of cations on the basis of 24 oxygens													
Si	10.86	11.12	10.86	10.96	10.38	11.18	11.08	11.04	10.27	10.53	11.20	11.26	11.45
Al	5.14	4.86	5.11	5.02	5.56	4.79	4.91	4.94	5.73	5.43	4.75	4.71	4.55
Fe	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.04	0.02	0.01	0.02
Ca	1.11	0.85	1.13	1.05	1.62	0.84	0.91	0.97	1.54	1.52	0.83	0.76	0.55
Na	2.90	3.14	2.82	2.87	2.35	3.08	3.02	2.91	2.58	2.46	3.10	3.24	3.41
K	0.04	0.04	0.10	0.08	0.06	0.10	0.08	0.10	0.04	0.03	0.15	0.05	0.03
An	28	21	29	27	41	21	23	25	37	38	21	19	14

Table 3. Representative electron microprobe analyses of amphibole.

	Diorite							Leucotonalite			Granodiorite	
sample	1038	1077		1527		1007		1129			1500	
SiO_2	44.93	44.32	44.38	45.33	46.40	44.81	45.56	47.47	47.94	48.35	43.73	41.47
TiO_2	1.57	1.90	1.61	1.56	1.31	1.24	1.51	0.93	1.09	1.11	1.40	1.63
Al_2O_3	8.84	8.79	8.77	7.94	7.38	8.45	8.73	6.22	5.90	6.29	8.94	9.52
FeO(T)	17.81	16.78	17.62	16.34	15.88	17.24	17.38	13.92	12.94	13.39	19.54	19.65
MnO	0.40	0.42	0.37	0.38	0.33	0.47	0.32	0.54	0.49	0.53	0.52	0.54
MgO	10.48	11.06	10.56	11.61	12.07	11.18	10.81	14.33	14.97	14.07	9.49	9.01
CaO	11.19	11.33	11.38	11.56	11.60	10.63	11.54	11.23	11.25	11.24	11.39	11.11
Na_2O	1.56	1.65	1.52	1.22	1.24	1.08	1.40	0.96	0.91	0.99	1.51	1.71
K_2O	1.03	1.04	1.10	0.88	0.78	0.87	0.92	0.34	0.40	0.29	1.15	1.30
Total	97.45	97.28	97.32	96.82	96.98	95.96	98.18	95.95	95.89	96.26	97.67	95.92
Number of cations on the basis of 23 oxygens												
Si	6.79	6.69	6.72	6.54	6.95	6.83	6.80	7.09	7.13	7.16	6.67	6.49
Ti	0.18	0.22	0.18	0.17	0.15	0.14	0.17	0.10	0.12	0.12	0.16	0.19
Al	1.51	1.57	1.57	1.35	1.31	1.52	1.54	1.10	1.04	1.10	1.61	1.76
Fe	2.25	2.12	2.32	1.97	1.99	2.20	2.17	1.74	1.61	1.66	2.50	2.57
Mn	0.05	0.05	0.05	0.05	0.04	0.06	0.04	0.07	0.06	0.07	0.07	0.07
Mg	2.36	2.49	2.38	2.50	2.70	2.54	2.41	3.19	3.32	3.11	2.16	2.10
Ca	1.81	1.83	1.85	1.79	1.86	1.74	1.85	1.80	1.79	1.79	1.86	1.86
Na	0.46	0.48	0.45	0.34	0.36	0.32	0.41	0.28	0.26	0.28	0.45	0.52
K	0.20	0.20	0.21	0.16	0.15	0.17	0.18	0.07	0.08	0.06	0.22	0.26
M/MF	51	54	51	56	53	57	53	65	67	65	46	45

Table 4. Representative electron microprobe analyses of biotite.

	Diorite								Granodiorite			Granite
sample	1038	1077	1527		1582		1007		1500	1615		1602
							Core	Rim				
SiO_2	36.18	36.55	36.52	36.72	36.27	36.24	36.99	36.65	36.09	37.19	36.79	37.03
TiO_2	3.44	4.77	4.52	4.27	4.83	4.32	4.34	4.20	3.06	2.84	3.16	2.59
Al_2O_3	15.47	14.74	14.39	14.34	14.30	14.37	15.92	15.67	15.49	14.71	14.05	15.25
FeO(T)	18.14	18.09	18.20	18.31	19.07	19.20	18.35	18.02	18.85	18.61	20.01	19.07
MnO	0.22	0.19	0.20	0.21	0.25	0.19	0.16	0.00	0.32	0.45	0.44	0.77
MgO	11.15	11.41	11.84	11.90	10.85	11.21	10.87	11.38	11.28	11.95	11.46	10.52
Na_2O	0.09	0.09	0.12	0.10	0.09	0.10	0.00	0.00	0.08	0.07	0.08	0.08
K_2O	9.97	9.58	9.76	9.91	9.65	9.54	9.95	9.54	9.88	10.05	9.73	9.73
Total	94.66	95.42	95.54	95.76	95.31	95.17	96.67	95.45	95.05	95.87	95.72	95.04
Number of cations on the basis of 24 oxygens												
Si	5.81	5.81	5.81	5.83	5.81	5.81	5.55	5.54	5.79	5.90	5.89	5.94
Ti	0.42	0.57	0.54	0.51	0.58	0.52	0.49	0.48	0.37	0.34	0.38	0.31
Al	2.93	2.76	2.70	2.69	2.70	2.72	2.81	2.79	2.93	2.75	2.65	2.88
Fe	2.44	2.40	2.42	2.43	2.55	2.57	2.30	2.28	2.53	2.47	2.68	2.56
Mn	0.03	0.03	0.03	0.03	0.04	0.03	0.02	0.00	0.04	0.06	0.06	0.11
Mg	2.67	2.70	2.81	2.82	2.59	2.67	2.43	2.57	2.70	2.83	2.74	2.51
Na	0.03	0.03	0.04	0.03	0.03	0.03	0.00	0.00	0.02	0.02	0.03	0.03
K	2.04	1.94	1.98	2.01	1.97	1.95	1.90	1.84	2.02	2.04	1.99	1.99
M/MF	52	53	54	50	50	51	51	53	52	53	51	50

LEUCOTONALITE

Field Relations and Petrography

Leucotonalite forms an elongate, northward-trending, lobate pluton, which covers an area of about 5 km^2. It is more or less concordant with structural trends in the metamorphic host rocks. The leucotonalite intruded mainly laminated quartz phyllites and schists except at its northern end where it cut across the stratigraphy into mafic schists and amphibolites.

The pluton is pervasively deformed and most of the observed contacts with the metamorphic rocks appear to be concordant and tectonized, and lack thermal effects. Therefore, it is presumed to be a syntectonic intrusion, emplaced like the diorites before or during the D_2 deformational event (see section on Structural Geology). However, the age of the leucotonalite relative to the diorite pluton is not known. To the west the leucotonalite is in faulted contact with volcanic rocks and to the south it is unconformably overlain by a cover of red beds of the Horton Group and onlapping grey limestones of the Windsor Group.

The leucotonalite is typically grey to grey-green, coarse grained and sheared. Near its margins it is particularly schistose and is commonly interlayered with quartz phyllites/schists showing no evidence of contact metamorphism.

In thin section, the leucotonalite typically displays intense alteration and protomylonitic textures. It consists mainly of plagioclase and quartz; the plagioclase occurs as highly sericitized and saussuritized augen within a matrix of granulated/strained quartz (30-40%) and chlorite. A few samples also contain relict amphibole and(or) biotite. Other

alteration minerals present include sericite, epidote and carbonate and the accessory minerals are sphene, apatite and opaque(s).

Electron microprobe analyses (Table 2) indicate that the plagioclase is of andesine composition (An_{31-38}). However, the analyses have low totals,

Table 5. Chemical analyses and normative mineralogies of diorite.

sample	1020	1038	1039	1077	1114	1144	1527	1582	1607	1609	1611	1007
SiO_2	53.00	52.48	49.83	51.72	54.57	52.26	51.65	50.62	55.60	55.80	57.49	56.33
TiO_2	1.70	1.92	1.88	1.85	1.59	1.90	1.17	2.06	1.12	1.44	1.44	1.49
Al_2O_3	17.81	15.67	15.19	15.88	16.31	16.10	16.29	15.91	15.89	15.71	15.60	17.16
Fe_2O_3	2.27	3.07	3.46	7.52	3.24	3.02	2.74	3.31	1.77	2.23	2.26	2.68
FeO	5.4	6.81	6.56	3.1	4.82	5.83	6.10	5.34	6.02	5.22	4.89	4.28
MnO	0.13	0.15	0.17	0.18	0.12	0.13	0.15	0.16	0.14	0.11	0.10	0.12
MgO	3.55	4.45	5.80	4.84	2.94	3.38	5.53	3.44	3.19	4.49	2.51	2.80
CaO	5.49	6.17	7.58	6.66	5.82	6.35	6.88	6.39	7.17	5.90	4.70	5.03
Na_2O	4.63	4.04	3.65	4.06	5.82	4.98	4.21	4.81	3.13	3.83	4.49	4.93
K_2O	2.43	2.21	2.30	1.96	1.99	2.43	2.04	2.40	1.91	2.28	2.91	2.15
P_2O_5	0.66	0.55	0.97	0.48	0.83	1.10	0.41	1.05	0.44	0.33	0.54	0.77
LOI	1.41	0.99	1.14	1.00	0.75	1.25	1.18	3.40	1.32	1.32	1.96	0.93
Total	98.48	98.51	98.53	99.25	98.80	98.73	98.35	98.89	97.70	98.74	98.89	98.67
Normative Mineralogy (wt%)												
Q	0.00	1.12	0.00	2.82	0.00	0.00	0.00	0.00	10.13	5.94	7.34	5.63
Or	14.80	13.34	13.89	11.79	12.01	14.74	12.42	14.85	11.65	13.85	17.69	13.01
Ab	40.25	34.95	31.67	39.94	50.15	43.13	36.65	42.58	27.36	33.18	39.17	42.66
An	21.27	18.62	18.74	19.62	12.77	14.81	20.06	15.41	24.58	19.46	14.27	18.73
Di	1.25	4.75	7.91	8.36	6.29	5.34	6.83	6.20	4.19	4.75	3.04	0.98
Hd	0.65	2.60	2.88	0.00	2.74	2.86	3.10	2.34	3.51	2.03	1.99	0.40
En	7.85	9.13	5.21	8.38	2.91	2.18	3.23	1.06	6.27	9.28	5.04	6.65
Fs	4.71	5.72	2.17	0.00	1.46	1.34	1.69	0.46	6.02	4.56	3.78	3.11
Fo	0.46	0.00	4.16	0.00	1.13	2.77	5.45	3.51	0.00	0.00	0.00	0.00
Fa	0.30	0.00	1.92	0.00	0.63	1.87	3.13	1.68	0.00	0.00	0.00	0.00
Mt	3.39	4.58	5.15	4.76	4.79	4.49	4.09	5.02	2.66	3.32	3.38	3.97
Il	3.33	3.74	3.66	3.57	3.08	3.68	2.29	4.09	2.19	2.79	2.80	2.89
Hm	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ap	1.58	1.31	2.28	1.13	1.94	2.62	0.98	2.52	1.03	0.79	1.27	1.80
Py	0.17	0.15	0.36	0.27	0.11	0.17	0.09	0.28	0.41	0.06	0.23	0.17
Trace Elements (ppm)												
Ba	1200	700	800	390	820	1200	670	970	350	700	950	4500
Rb	44	40	29	38	28	41	38	44	60	58	57	33
Sr	790	970	2500	1400	1450	1040	770	765	305	890	790	830
Li	12	9	8	9	10	10	10	16	21	14	13	7
F	780	810	850	170	670	940	670	870	630	680	920	560
B	3	3	5	2	2	2	2	5	5	3	8	4
Be	2.3	1.7	1.9	2.9	1.9	2.3	2.3	1.8	2.6	3.9	3.6	2.5
Mo	1.8	1.4	1.6	1.6	1.7	2.7	1.6	2	1.2	1.0	1.2	1.4
Cu	21	49	62	29	22	23	20	24	37	20	16	26
Pb	6	7	26	8	11	8	5	12	106	9	13	12
Zn	119	790	115	124	112	102	100	84	8	74	126	101
Sn	2	1.2	1	0.9	1	1.7	0.9	2	2	0.7	2.1	4.6
W	4	4	4	4	4	4	4	4	4	4	4	4
U	0.9	0.8	1.1	0.7	1.0	0.8	0.6	0.9	0.9	1.1	2.4	0.7
Th	4	5	3	3	4	2	2	3	7	3	2	2
S	820	740	1720	1360	520	800	440	1340	1920	340	1180	860

probably a result of mineral alteration, and may not be accurate. The relict amphibole is magnesio-hornblende (Table 3), with low TiO_2, Al_2O_3, $Fe_2O_3^T$, Na_2O, and K_2O and high MgO and MnO compared to amphiboles in the diorite. No reliable biotite analyses could be obtained from the analyzed thin sections.

On the basis of their high quartz and very low K-feldspar modal contents, the rocks are tonalites but given their low mafic mineral contents, they are more appropriately referred to as leucotonalites. The rocks could also be termed calcic trondhjemite or plagiogranite (Barker, 1979; Coleman and Donato, 1979).

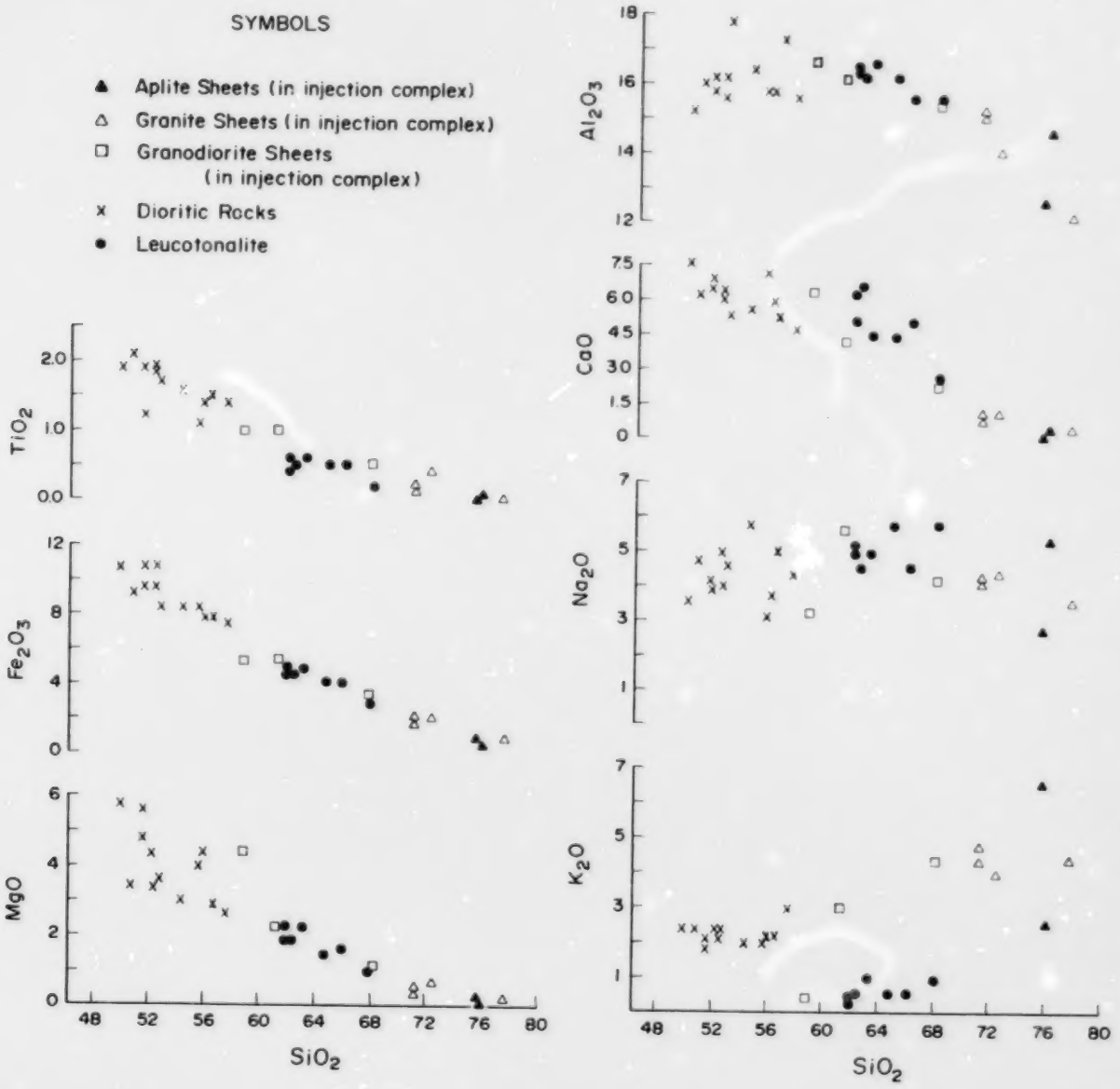


Figure 4. SiO_2 variation diagrams for major elements in granitoid units.

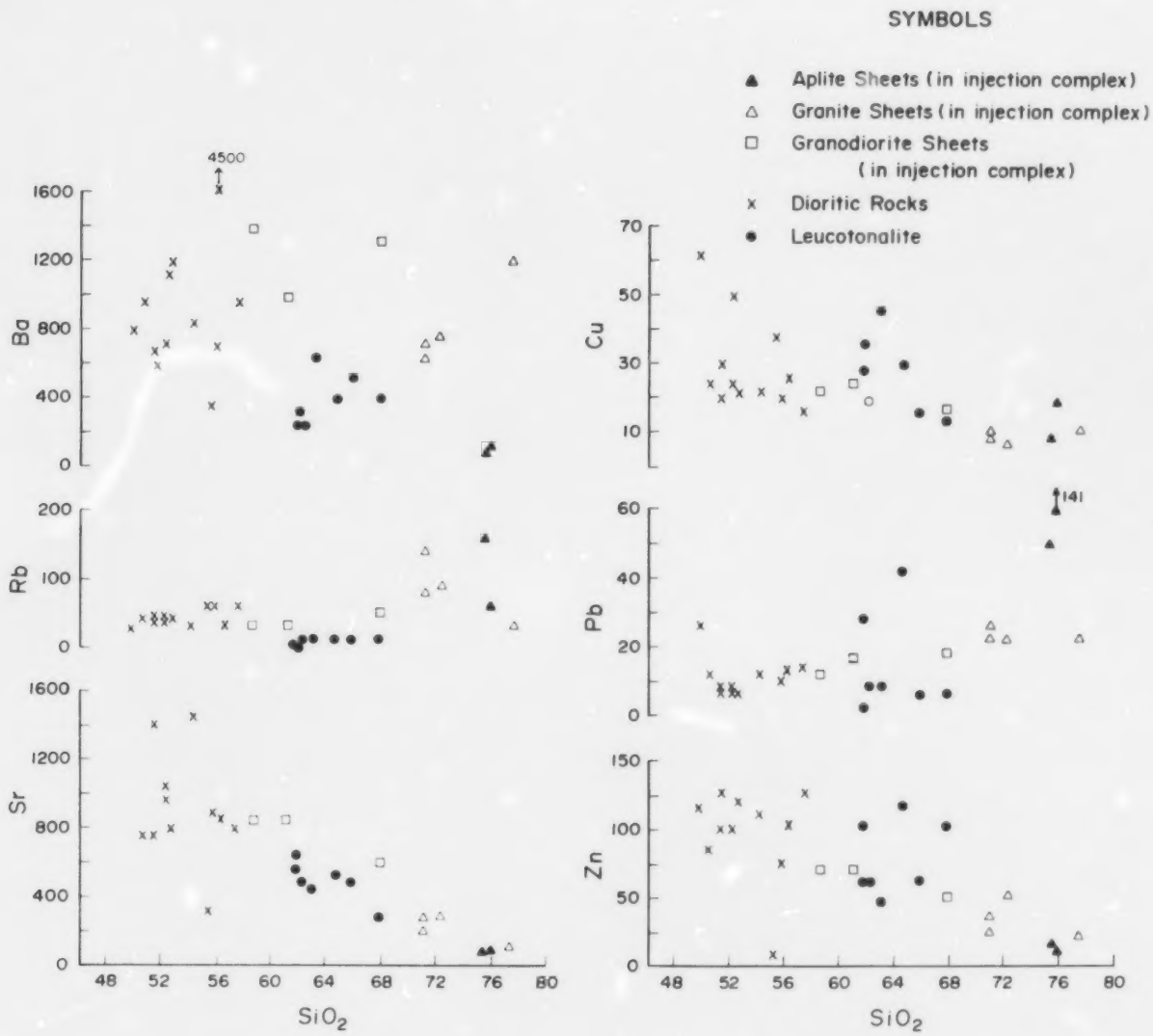


Figure 5. SiO_2 variation diagrams for selected trace elements in granitoid units.

Geochemistry

The leucotonalite ranges in SiO_2 values from 62-68% (Table 7). K_2O values are uniformly very low (< 1%), but Na_2O, CaO and Al_2O_3 are relatively high, consistent with the abundant andesine in these rocks. Al_2O_3, Fe_2O_3 and MgO all show good negative correlations with SiO_2 (Fig. 4).

Rb contents are very low (2-11 ppm), corresponding to the uniformly low K_2O values. However, Sr values are normal and show moderately good negative correlation with SiO_2 (Fig. 5). Ba values are scattered and show a weak positive correlation with SiO_2. Cu, Pb and Zn contents are also somewhat scattered with a few samples showing slightly elevated values (Fig. 5). Sn values are low but varied, whereas U, Th and Be are distinctly and uniformly low (Table 7).

The leucotonalite samples range from quartz diorite to granodiorite or tonalite in normative mineralogy

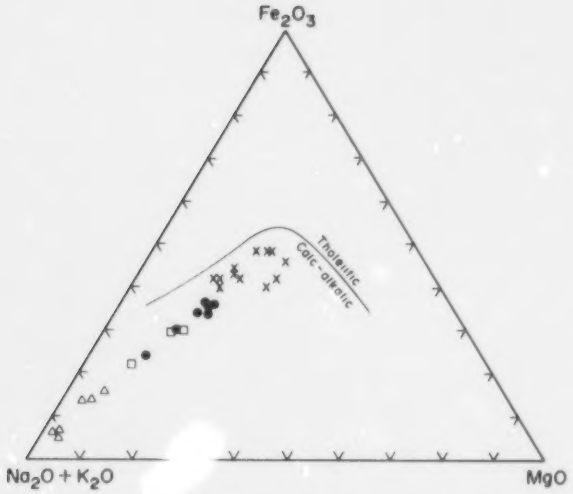


Figure 6. AFM diagram for granitoid units. Tholeiitic-calc-alkalic dividing line from Irvine and Baragar (1971).

(Fig. 7). Compared to the average trondhjemite of Barker (1979), the leucotonalite has lower SiO_2 and correspondingly higher $Fe_2O_3{}^T$ and MgO.

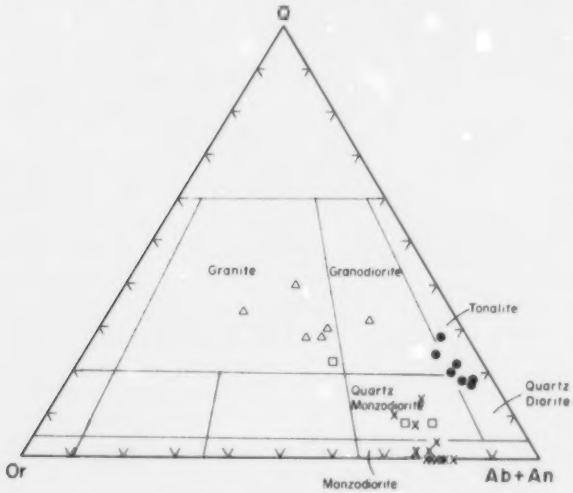


Figure 7. Normative quartz-orthoclase-plagioclase diagram for granitoid units.

On a plot of An-Ab-Or, the leucotonalite falls mainly in the tonalite field, although two samples plot in the trondhjemite field (Fig. 9a). They scatter in and above the oceanic plagiogranite field of Coleman and Peterman (1975); but are lower in SiO_2 than continental trondhjemites (Fig. 9b). Neither of these classification diagrams is considered definitive because of the strong possibility that K_2O has been disturbed by alteration. More reliable rare earth element data (Table 6) show light-enriched patterns (Fig. 8) very similar to those of continental margin trondhjemites (Arth, 1979).

It is proposed that the Mabou leucotonalite is akin to an island-arc or continental-margin trondhjemite as described by Arth (1979). Such rocks form in a subduction environment and are derived from melting of amphibolitic or eclogitic source rocks (Arth, 1979). It is likely that the leucotonalite and diorite are comagmatic, and form a "calc-alkalic bimodal suite" like that described by Arth (1979). The geochemical data are consistent with both the partial melting and fractional crystallization models proposed by Arth (1979) and in references cited therein. A detailed consideration of the petrogenesis of these rocks is beyond the scope of this report.

GRANITIC COMPONENTS OF THE INJECTION COMPLEX

Introduction

The main granitic components of the injection complex include porphyritic granodiorite, granite, syenogranite, felsite and minor pegmatite. These lithologies occur mainly as sheets within the banded and amphibolitic gneisses which make up the bulk of the complex.

Granodiorite

The granodiorite occurs as numerous sheets, from several to 70 m thick, distributed throughout the complex and also within the diorite plutons. The sheets are best exposed on the coastline between Sight Point and Port

Table 6. Rare earth element data (in ppm) for diorite and leucotonalite.

	La	Ce	Nd	Eu	Gd	Dy	Er	Yb
Diorite								
sample 1038	113.3	89.5	59.2	27.0	20.2	15.0	11.3	8.5
1039b	100.6	98.9	64.0	30.9	25.5	12.0	9.2	6.6
1077	65.8	68.0	44.2	25.0	18.2	14.0	12.0	9.2
Leucotonalite								
sample 1128	17.6	21.6	13.8	15.9	6.1	3.8	4.0	3.0
1129	17.9	18.6	14.0	16.2	4.9	4.1	5.4	3.3

Ban and the largest sheet forms a mappable unit near Sight Point. The sheets are generally concordant with the foliation in the host rocks and are well foliated. They consist of coarse grained dark biotite-hornblende granodiorite with large crystals of pink microcline; internal deformation is pervasive so that the microcline occurs as augen within a mainly gneissic matrix.

Plagioclase, microcline, biotite, and hornblende, with abundant accessory apatite, sphene, and magnetite, are seen in thin section. The plagioclase is of oligoclase composition (Table 2) and is partly saussuritized. Microcline is about Or_{90} in composition (Table 8). The amphibole is similar in composition to that in the diorite (Table 3) but is more iron-rich. Biotite composition is also similar to that in the diorite but has lower TiO_2 and higher Mn (Table 4).

The granodiorites range in SiO_2 values from 59-68% (Table 9). Most of the major oxides, except Na_2O and K_2O which are more scattered, show good negative correlations with SiO_2 (Fig. 4). Trace element values appear normal for this range of SiO_2 values (Table 9, Fig. 5) with the exception of high Ba contents.

Granite, Syenogranite, Aplite and Pegmatite

Red to pink granite occurs in sheets that mainly have the same mode of occurrence and distribution as the granodiorite sheets but are less abundant. The granite, which is variably deformed and altered, is medium- to coarse-grained, leucocratic and occurs in sheets from 1 to more than 80 m thick. The thinner sheets are more obviously foliated than the thicker ones but all show evidence of cataclasis.

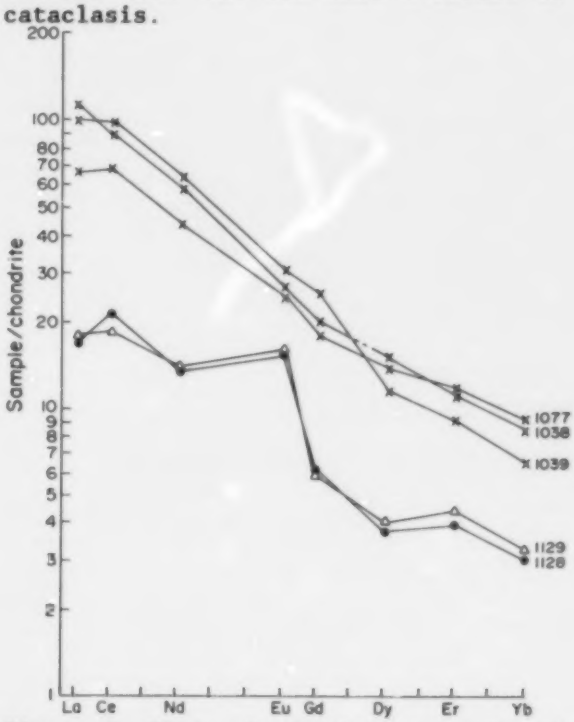


Figure 8. Plot of chondrite-normalized rare-earth element data from Table 6. Chondrite values from Hanson (1980). Cross, dioritic sample; triangle, leucotonalite sample 1129; circle, leucotonalite sample 1128.

Table 7. Chemical analyses and normative mineralogies of leucotonalite.

sample	1064	1067	1071	1128	1129	1562	1661
%							
SiO_2	64.72	67.92	66.01	62.60	62.00	61.87	63.23
TiO_2	0.45	0.24	0.50	0.53	0.58	0.39	0.56
Al_2O_3	16.22	15.59	15.62	16.21	16.40	16.38	16.57
Fe_2O_3	0.12	0.28	0.94	0.95	0.54	0.32	0.52
FeO	3.42	2.38	2.62	3.10	3.57	4.14	3.82
MnO	0.07	0.06	0.08	0.10	0.10	0.08	0.06
MgO	1.47	0.98	1.55	1.77	1.87	2.18	2.11
CaO	4.36	2.74	5.01	6.45	6.21	5.18	4.52
Na_2O	5.82	5.77	4.54	4.56	5.07	5.27	5.00
K_2O	0.65	1.09	0.60	0.54	0.36	0.42	0.90
P_2O_5	0.17	0.10	0.15	0.16	0.16	0.18	0.18
LOI	1.17	1.70	1.50	1.63	1.72	2.03	1.97
Total	98.64	98.85	99.12	98.59	98.58	98.44	99.44
Normative Mineralogy (%)							
Q	16.21	22.04	24.55	18.59	15.58	14.22	16.47
C	0.00	0.19	0.00	0.00	0.00	0.00	0.00
Or	3.89	6.64	3.64	3.24	2.14	2.52	5.40
Ab	50.47	50.27	39.28	39.81	44.22	46.27	43.42
An	16.73	13.27	21.03	22.91	21.67	20.55	20.68
Di	1.58	0.00	1.58	4.05	3.77	1.98	0.51
Hd	2.12	0.00	1.21	3.37	3.77	2.16	0.49
En	3.00	2.51	3.20	2.67	3.04	4.72	5.13
Fs	4.59	3.96	2.81	2.56	3.49	5.92	5.64
Mt	0.18	0.40	1.38	1.39	0.81	0.47	0.74
Il	0.86	0.47	0.97	1.04	1.12	0.77	1.07
Ap	0.38	0.24	0.36	0.38	0.38	0.41	0.41
Py	0.00	0.00	0.00	0.00	0.02	0.02	0.04
Trace Elements (ppm)							
Ba	390	400	530	250	330	240	620
Rb	8	11	6	5	2	4	10
Sr	500	295	475	460	630	540	440
Li	17	10	14	5	10	17	11
F	400	320	290	340	280	330	550
B	8	10	6	7	10	9	10
Be	1.3	2.5	2.4	0.7	1.2	2.4	2.3
Mo	3.0	1.6	1.7	1.5	2.6	0.7	1.0
Cu	29	13	16	20	27	36	45
Pb	42	5.0	5.0	8.0	27.0	62	47
Zn	117	100	61	62	101	62	47
Sn	6.4	0.5	0.5	0.5	4.4	0.5	3.0
W	4	4	4	4	4	4	4
U	0.6	0.6	0.5	0.4	0.3	0.5	0.8
Th	2	2	2	2	2	2	2
S	80	60	60	40	120	140	200

The granite contains perthitic orthoclase (Or_{91}, Table 8) and oligoclase (An_{14}, Table 2) occurring as augen within a groundmass of granulated quartz and deformed biotite (altered to chlorite), plus sericite, apatite and zircon. The biotite is lower in TiO_2 and higher in MnO than biotite in the granodiorite (Table 4).

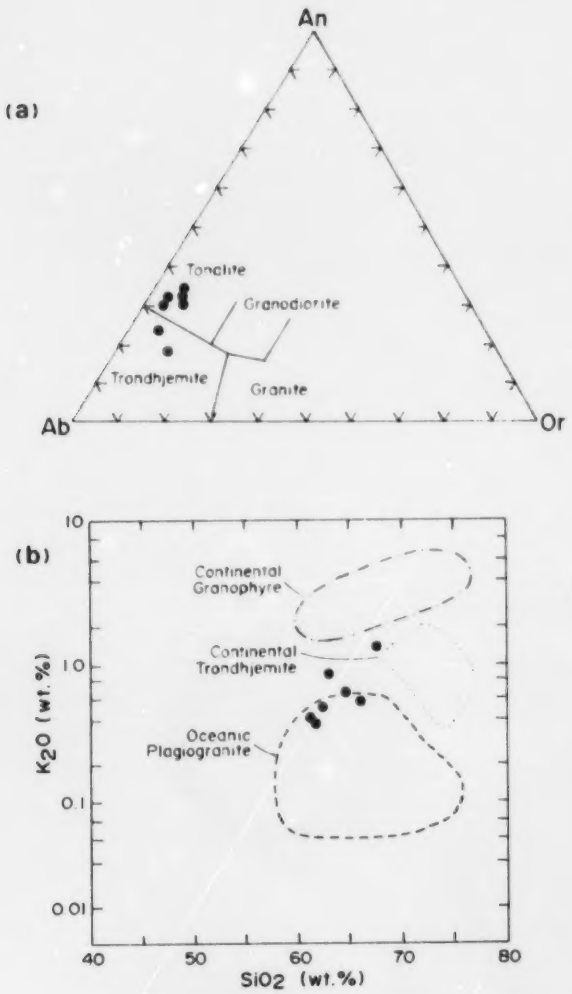


Figure 9. Mabou leucotonalite samples (black circles) plotted on:
(a) a normative anorthite-albite-orthoclase diagram with fields from Barker (1979) and
(b) a K_2O-SiO_2 diagram with fields from Coleman and Peterman (1975).

A variety of smaller sheets and irregular bodies of syenogranite, aplite and minor pegmatite are closely associated with the granite (and to some extent the granodiorite). The syenogranite is finer grained and more leucocratic than the granite. It contains microcline and plagioclase augen and rare garnet in a deformed matrix of granulated quartz, muscovite and minor biotite. The aplites are even finer grained and contain a higher proportion of K-feldspar to plagioclase. Rare pegmatites consist of K-feldspar, quartz, plagioclase and mica.

Chemically, the granites display a range of SiO_2 values from 71-78% (Table 9). The other major elements show good negative correlations with SiO_2, except for Na_2O and K_2O which are more scattered (Fig. 4). Trace element values (Fig. 5) are generally normal, with Ba and Rb showing the most scatter.

The two analyses of aplite indicates that major and trace element chemistry is similar to that of the granite except for more varied K_2O and Na_2O values (Table 9; Fig. 4), high Pb and low Ba (Fig. 5).

SILURIAN(?) SEDIMENTARY UNIT

Several outcrops of varied sedimentary rocks occur along the western edge of the Mabou Highlands. They clearly do not belong to any of the Carboniferous units found in the same general area and in accordance with previous workers in the area, these rocks are tentatively assigned to the Silurian.

Three outcrops along the Mabou Mines Road occur as inliers within red beds of the Horton Group. These inliers have been explained by Wait (1959) as pre-Horton paleotopographic features and consist of drab grey-brown quartz arenites, siltstones and shales, the latter reported to locally contain rhynchonellid brachiopods and other

Table 8. Representative electron microprobe analyses of potassium feldspars.

	Granodiorite		Granite	
sample	1500	1615	1602	
SiO_2	64.26	64.33	63.94	65.17
Al_2O_3	18.72	18.56	18.40	18.59
FeO (T)	0.06	0.12	0.08	0.08
CaO	0.02	0.05	0.00	0.04
Na_2O	1.21	1.25	1.00	1.01
K_2O	15.01	15.29	15.57	15.77
BaO	1.48	--	--	0.18
Total	100.76	100.42	99.02	100.86
Number of cations on the basis of 24 oxygens				
Si	11.88	11.90	11.94	11.95
Al	4.01	4.05	4.05	4.02
Fe	0.01	0.02	0.01	0.01
Ca	0.01	0.01	0.00	0.01
Na	0.43	0.45	0.36	0.36
K	3.54	3.61	3.71	3.69
Ba	0.11	--	--	0.01
Or	89	89	91	91

fauna, an assemblage which has a maximum stratigraphic range of Upper Ordovician to Devonian (Phinney, 1956). The rhynchonellid morphology was thought to more closely resemble that of pre-Devonian forms, thus a Silurian age was assigned (Phinney, 1956) and stratigraphic correlation was made with similar rocks in the Arisaig area (Boucot et al., 1974). Fossiliferous grey sandstone and limestone pebbles from conglomerates in the lower part of the Horton Group near Mabou Harbour and Mabou Mines also contain brachiopod faunas believed to be of Silurian age (Norman, 1935). Such occurrences tend to support the interpretation of Wait (1959) concerning the stratigraphic relationship between the Silurian(?) rocks and the Mississippian Horton Group.

A fourth occurrence of similar rocks is found in a fault sliver south of Sight Point, jammed between metamorphic, volcanic and Carboniferous sedimentary rocks. It consists of sheared and steeply dipping multi-coloured arenite, grey siltstone and black and purple shale with some dolostone layers. No fossils were found in these rocks but they are correlated on the basis of lithology with the three outcrops of Silurian(?) rocks found along the Mabou Mines Road.

The relationship of these sedimentary rocks with the nearby Mabou volcanic-sedimentary unit is not clear. The only mutual contact seen is faulted and elsewhere they are separated by Horton Group sedimentary rocks. The volcanic rocks are interbedded in part

Table 9. Chemical analyses and normative mineralogies of intrusive sheets in the injection complex.

	Granodiorite			Granite				Aplite	
	1500	1504	1615	1108	1509	1602	1612	1626	1515
SiO_2	58.91	61.28	68.16	72.41	71.38	71.40	77.55	75.90	75.79
TiO_2	0.99	0.96	0.47	0.35	0.21	0.18	0.03	0.11	0.03
Al_2O_3	16.53	16.28	15.32	13.95	15.05	15.12	12.26	14.55	12.69
Fe_2O_3	1.38	1.40	0.87	0.47	0.80	0.80	0.11	0.03	0.15
FeO	3.55	3.44	2.08	1.36	0.79	0.90	0.45	0.50	0.50
MnO	0.08	0.08	0.06	0.06	0.03	0.04	0.02	0.01	0.02
MgO	2.12	2.18	0.94	0.62	0.37	0.46	0.11	0.05	0.16
CaO	4.48	4.24	2.27	1.16	0.83	1.16	0.66	0.74	0.26
Na_2O	6.31	5.59	4.24	4.31	4.18	4.28	3.50	5.49	2.83
K_2O	3.13	2.94	4.46	4.07	4.87	4.47	4.43	2.66	6.51
P_2O_5	0.36	0.36	0.15	0.11	0.04	0.06	0.02	0.00	0.00
LOI	0.61	0.85	0.71	0.51	0.43	0.40	0.33	0.20	0.30
Total	98.45	99.59	99.73	99.39	98.98	99.27	99.47	100.18	99.24
Normative mineralogy (wt%)									
Q	0.00	6.33	19.84	28.26	26.40	26.40	38.74	31.89	33.72
C	0.00	0.00	0.00	0.61	1.53	1.32	0.55	1.32	0.55
Or	18.88	17.56	26.65	24.31	29.24	26.69	26.44	15.68	38.88
Ab	54.61	47.92	36.24	36.91	35.90	36.64	29.88	46.45	24.13
An	7.71	10.79	9.66	5.11	3.86	5.38	3.17	3.62	1.25
Di	6.30	4.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Hd	4.05	2.50	0.26	0.00	0.00	0.00	0.00	0.00	0.00
En	1.17	3.55	2.23	1.56	1.91	1.16	0.25	0.13	0.40
Fs	0.86	2.42	2.26	1.66	0.50	0.78	0.69	0.69	0.79
Fo	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fa	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Mt	2.03	2.06	1.27	0.69	1.18	1.17	0.16	0.00	0.00
Il	1.90	1.85	0.90	0.65	0.39	0.33	0.06	0.19	0.06
Ap	0.83	0.82	0.35	0.24	0.09	0.14	0.05	0.00	0.00
Py	0.00	0.00	0.04	0.00	0.00	0.00	0.02	0.08	0.00
Trace Elements (ppm)									
Ba	1400	1000	1300	750	630	700	1200	117	65
Rb	29	30	53	85	78	140	33	57	156
Sr	840	820	590	290	210	290	115	95	65
Li	8	10	10	22	10	10	2	1	2
F	620	540	520	520	420	470	260	180	170
B	2	2	2	3	2	2	4	3	2
Be	3.2	1.9	6.5	7.7	6.5	9.5	5.?	13.0	3.7
Mo	1.4	1.8	0.?	1.6	1.6	1.6	1.7	2.0	1.6
Cu	21	23	15	6	7	9	10	17	8
Pb	11	16	17	22	21	25	21	141	49
Zn	70	71	52	51	27	36	22	12	15
Sn	0.5	0.8	1.3	1.5	1.0	0.7	0.5	0.5	0.5
W	4	4	4	4	4	4	4	4	4
U	1.3	1.6	1.8	3.7	3.7	3.0	0.5	10.3	1.3
Th	3	6	10	19	20	20	6	28	11
S	60	60	200	40	40	40	140	460	40

with red beds much more akin to the Horton Group than to these Silurian(?) clastic rocks.

VOLCANIC-SEDIMENTARY UNIT

FIELD RELATIONS AND PETROGRAPHY

A predominantly volcanic sequence with locally interbedded red beds outcrops in a north-trending fault block, 1-2 km wide, along the western margin of the Mabou Highlands and also in a small, partly faulted outlier, 1 km east of Port Ban.

In the fault block, two subunits are recognized. The lower(?) subunit (D_{CT}) consists of a uniform thick sequence of grey to buff quartz-feldspar crystal tuffs. These are massive, structureless rocks containing abundant fractured and embayed quartz crystals and saussuritized feldspar crystals, rare lithic fragments and minor chlorite and opaque minerals in a crystalline felsic groundmass. The only other rocks present in this sequence are mafic dykes.

The upper(?) mixed subunit (D_{VS}) consists of grey-green to maroon, porphyritic basalt and andesite flows, lithic-crystal tuffs, reddish pebbly arkose and siltstone. Layering generally dips variably north and east and fine grained tuffs and siltstone are commonly cut by east-west slaty cleavage. This suggests that these rocks are internally folded but structural data (see Section on Structural Geology IX) are insufficient to clearly define the scale and style of deformation. Veining and breccia-filling by quartz-calcite and locally by barite (Felderhof, 1978) are common features.

The basalt-andesite flows are fine grained, holocrystalline, locally amygdaloidal rocks, typically with either relatively fresh albite or highly saussuritized plagioclase phenocrysts and flow-aligned laths in a groundmass of chlorite, epidote, calcite and hematite. Clusters of epidote and lesser chlorite may represent original mafic phenocrysts. Amygdales are mainly filled with calcite or quartz. The tuffs, which include vitric, crystal and lithic tuffs, generally contain variable proportions of small lithic fragments (mainly basaltic to andesitic), fractured crystals of plagioclase and quartz, chloritic patches and devitrified glass in fine grained matrices of epidote, chlorite, calcite, feldspar and quartz. Voids, which are common in these rocks, are filled with chlorite, calcite, quartz and locally prehnite. Sedimentary rocks in this subunit include red to maroon conglomeratic arkoses and locally cleaved siltstones and minor shales.

Volcanic and sedimentary rocks in the small outlier east of Port Ban are included in the lower subunit of the Mabou volcanic sedimentary unit. They consist of grey and pink flow banded rhyolites with minor purple tuffaceous interbeds.

All of the rocks in the volcanic-sedimentary unit are extensively altered: plagioclase is strongly saussuritized, original mafic minerals are completely epidotized and(or) chloritized and opaque phases are hematitized. Calcite, quartz, chlorite and rare prehnite occupy veinlets, amygdales and(or) interstitial patches. The degree to which these rocks, in particular the mafic volcanic rocks, have been altered is indicated by their high loss-on-ignition values (Table 10) and by a plot of (Na_2O + K_2O) vs. $K_2O/(Na_2O + K_2O)$ values (after Hughes, 1972), in which all of the mafic rocks plot in the "spilite" field (Fig. 10a). It is not clear whether this alteration reflects hydrothermal alteration or low-grade burial metamorphism but its pervasive nature and mineral assemblages suggest the latter.

Table 10. Major and trace element analyses of volcanic rocks.

	FLOWS							TUFFS		
sample	1054B	1624	1671	1672	1056	1050	1541	1131	1669	1154
%										
SiO_2	42.8	43.8	49.5	49.5	52.1	54.5	58.6	51.9	65.5	71.6
TiO_2	3.4	1.4	1.3	1.3	1.2	1.4	0.58	1.2	0.38	0.33
Al_2O_3	15.5	15.2	15.7	16.1	17.0	16.1	17.3	17.8	15.8	14.8
Fe_2O_3	3.5	1.9	9.0	4.8	9.4	3.4	3.5	8.1	0.24	1.3
FeO	11.1	8.0	3.3	7.2	2.2	5.7	3.6	2.6	2.9	1.2
MgO	7.6	8.6	4.7	4.7	3.9	4.6	2.1	3.8	1.3	0.89
MnO	0.25	0.21	0.20	0.17	0.16	0.31	0.23	0.17	0.07	0.08
CaO	7.0	8.7	4.6	6.2	3.5	4.1	2.3	7.5	2.7	1.6
Na_2O	2.6	2.7	5.4	4.1	6.0	5.7	5.9	2.8	6.7	4.7
K_2O	0.06	0.14	0.41	0.05	0.51	0.26	1.2	0.57	0.51	3.0
P_2O_5	0.67	0.37	0.15	0.21	0.33	0.65	0.40	0.22	0.13	0.1
LOI	4.7	8.5	4.7	4.4	3.6	2.9	3.3	3.6	2.7	1.1
Total	99.2	99.6	98.9	98.8	99.9	99.5	99.0	100.2	98.9	100.7
ppm										
Rb	15	13	16	14	18	14	22	19	17	72
Zr	295	120	115	70	85	120	155	65	50	155
Li	55	35	30	29	32	59	26	60	11	11
Y	41	31	28	20	20	29	35	18	10	24
Nb	20	8	6	9	10	9	11	8	6	11
Pb	3	5	2	2	2	2	2	8	9	5
Zn	205	95	131	121	96	155	167	131	66	65
Cu	138	79	9	62	24	26	22	123	43	9
Co	56	47	41	33	31	20	10	34	8	2
Ni	146	142	12	11	20	34	5	12	16	10
Cr	66	160	14	10	13	21	8	11	10	24

GEOCHEMISTRY AND TECTONIC SETTING

Seven samples from basaltic to andesitic flows in the upper subunit and three lithic-crystal tuff samples, two from the lower subunit and one from the upper subunit, were analyzed (Table 10). The flows range in SiO_2 values from 45-61% (calculated on a volatile-free basis), corresponding to basaltic to andesitic compositions, whereas the lithic-crystal tuffs range from andesitic to rhyodacitic in composition (Fig. 10b). TiO_2 values, with the exception of sample 1054B, are less than 1.5% (Table 10) and Zr/TiO_2 and Nb/Y ratios are low, suggesting that these rocks are subalkaline in character (Fig. 10b).

On Figure 10c, the mafic to intermediate samples plot in the tholeiitic field of Miyashiro (1974), suggesting that these may be tholeiitic rocks if $Fe_2O_3{}^T$ values in particular are not very disturbed by alteration. On a Ti-Zr-Y discrimination diagram (Fig. 10d) the mafic samples straddle the boundary between the field for within-plate basalts and the overlapping fields for ocean-floor and arc basalts. It has been demonstrated (Holm, 1982) that continental tholeiites do not consistently plot in the within-plate field on the Ti-Zr-Y discrimination diagram, and instead commonly also plot in the ocean-floor and arc basalt fields. A similar ambiguous situation is shown by a Ti/Y vs. Nb/Y plot (Fig. 10e). Half of the

samples plot within the continental tholeiite field, but the others extend into the ocean-floor and island-arc fields. Less ambiguous is the Zr/P_2O_5 vs. Nb/Y plot (Fig. 10f, after Winchester and Floyd, 1977) in which the samples plot largely in the continental tholeiite field and partly in the overlapping fields of continental and oceanic tholeiites.

Hence, although none of the discrimination diagrams unequivocally defines the magma type/tectonic setting, they collectively suggest that these rocks have continental tholeiitic affinity. The close spatial association of the volcanic rocks with red clastic rocks of obvious continental provenance also implies that the volcanic rocks are of continental origin and hence may have been generated in a within-plate extensional environment.

CORRELATIVES OF THE MABOU VOLCANIC-SEDIMENTARY UNIT

Two possible correlatives of the Mabou volcanic-sedimentary unit are the Fisset Brook Formation of Devono-Carboniferous age in Cape Breton Island and the Dunn Point and equivalent formations of Ordovician-Silurian age in the Antigonish and Cobequid Highlands (Boucot et al., 1974; Keppie, et al., 1978). Both are mainly bimodal suites which have been

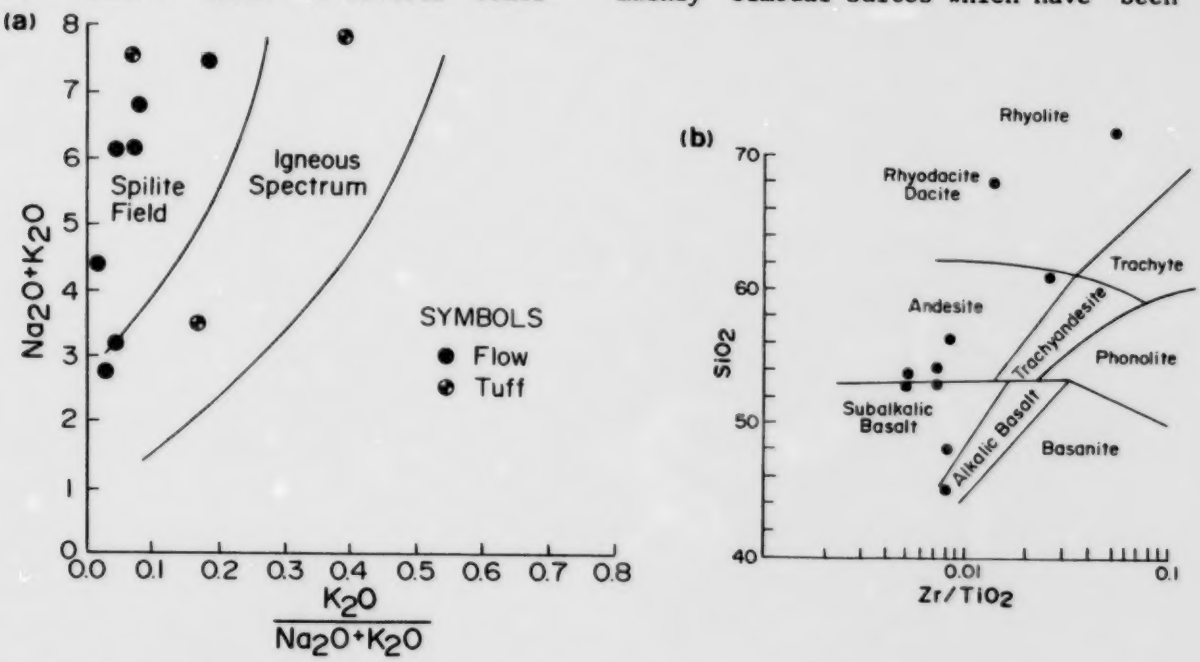


Figure 10. Geochemical discrimination diagrams for Silurian-Devonian(?) volcanic rocks.

(a) $Na_2O + K_2O$ vs. $K_2O/(Na_2O + K_2O)$ diagram (after Hughes, 1972);

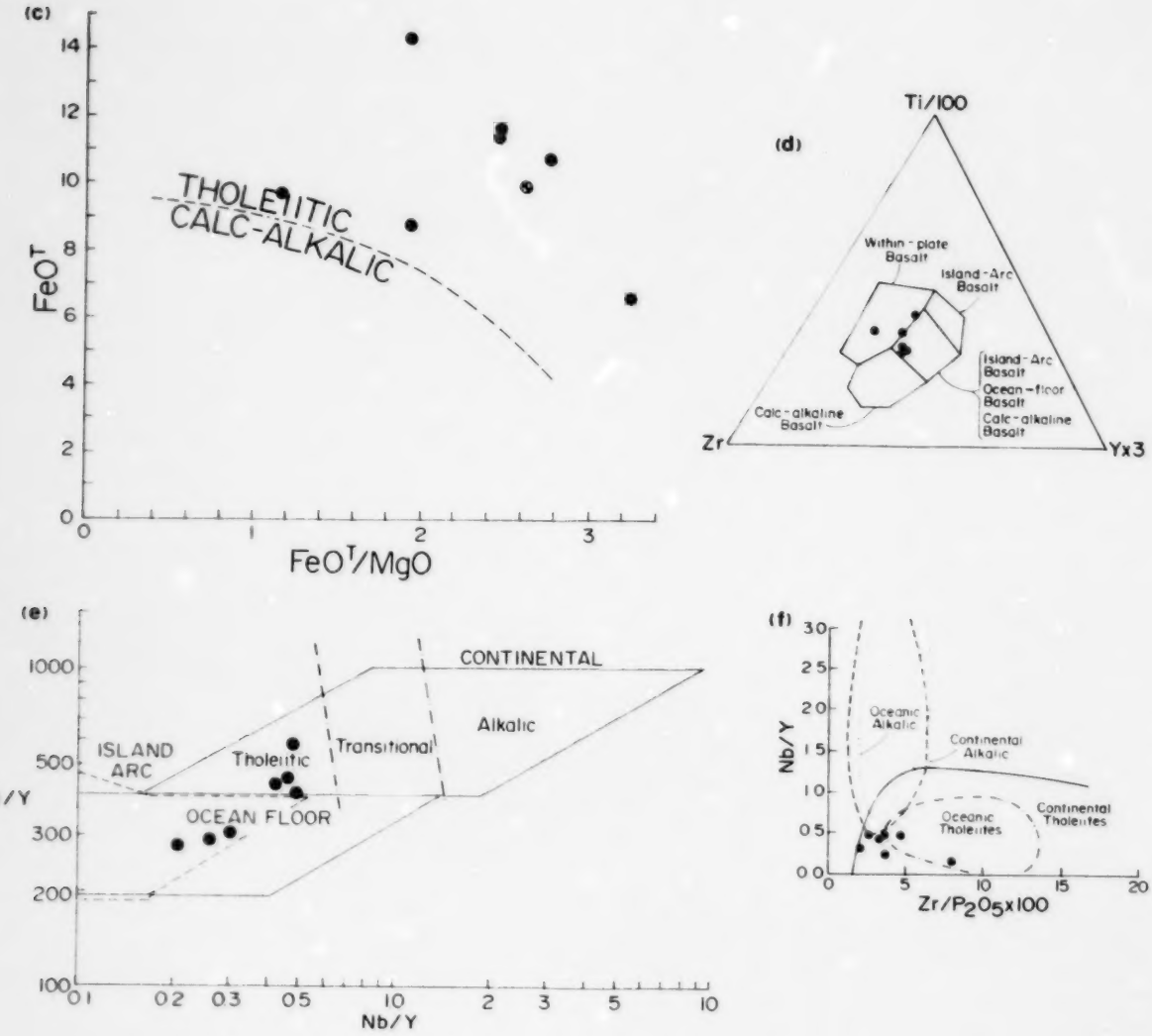
(b) SiO_2 vs. Zr/TiO_2 diagram (after Winchester and Floyd, 1977);

(c) Basaltic and andesitic samples plotted on an FeO^T vs. FeO^T/MgO diagram (after Miyashiro, 1974) (over);

(d) Basaltic samples plotted on a Zr-Ti-Y diagram (after Pearce and Cann, 1973) (over);

(e) Basaltic samples plotted on a Ti/Y vs. Nb/Y diagram (after Pearce, 1982) (over);

(f) Basaltic samples plotted on a Nb/Y vs. Zr/P_2O_5 diagram (after Winchester and Floyd, 1977) (over).



shown through immobile element geochemistry to be tholeiitic transitional to alkalic, and generated in a within-plate continental environment (Keppie and Dostal, 1980).

All three groups are geochemically similar except that the Mabou volcanic rocks are less distinctly bimodal and have generally lower Nb, Y and Zr values which presumably reflect their more strongly subalkaline (tholeiitic) character. The Fisset Brook Formation outcrops in close proximity to the Mabou Highlands (e.g. in the Lake Ainslie area only 25 km to the east) and lithological and stratigraphic similarities are apparent between the Mabou volcanic-sedimentary sequence and, for example, the Lowland Cove sequence of the Fisset Brook Formation (Smith and Macdonald, 1981). On the other hand, the apparent spatial association of the Mabou unit with Silurian fossiliferous rocks suggests correlation with the Ordovician-Silurian units of northern Nova Scotia which consistently underlie Silurian fossiliferous sequences (J. B. Murphy, personal communication, 1986). In this report, correlation with the Fisset Brook Formation is favoured and the Mabou volcanic-sedimentary unit is

assigned a tentative Siluro-Devonian age. This is based on the reasoning that the metamorphic units in the Mabou Highlands may be Ordovician to Silurian (see Discussion) and the unmetamorphosed volcanic-sedimentary unit is not considered to be correlative with those rocks on the basis of this study.

STRUCTURAL GEOLOGY

INTRODUCTION

All of the rocks in the Mabou Highlands are deformed. The older crystalline rocks, both metamorphic and plutonic, are foliated, the younger volcanic and sedimentary rocks are folded, and all are cut or juxtaposed by mainly north- and northwest-trending faults.

Metamorphic rocks in the core of the Mabou Highlands have undergone polyphase folding, with evidence for at least three phases of deformation. The first two created mainly north-trending penetrative structures, whereas the third produced more sporadically developed east-west cross-structures. The leucotonalite and diorite plutons which intruded these metamorphic rocks are distinctly elongated parallel to the main north-south structural trends and are pervasively foliated.

POLYPHASE STRUCTURE OF THE METAMORPHIC ROCKS

Three sets of minor structures (associated with deformational events D_1, D_2 and D_3) are recognized in the metamorphic rocks.

D_1 Structures

The dominant minor structure of D_1 age in the area is the S_1 foliation which is either a strong penetrative schistosity or a gneissosity depending on rock type and(or) metamorphic grade. These foliations in general strike north to north-northwest and dip steeply eastward (Figs. 11 and 12).

Various strong lineations (L_1), developed within the foliation planes, include: (1) fine rodding, (2) intersections of S_0 and S_1 and (3) stretched lapilli clasts in lithic tuffs. These lineations plunge mainly north-northwest but also south-southeast and show considerable scatter in orientation, presumably due to re-orientation by later folding (Fig. 12a).

F_1 minor folds are rare, the only ones observed being intrafolial folds which show evidence of strong transposition, i.e. disruptive movement along the foliation planes (Fig. 13a). A major F_1 synform is inferred to be the main structural feature of the area (Figs. 11 and 12a), based on the apparent southward closure of the distinctive banded schist formation with its characteristic metarhyolite layers, together with the northward plunge of most L_1 lineations. Supporting evidence is weak; there is a general lack of F_1 minor folds as described above and the stratigraphy of the eastern limb of the inferred synform is obscured by increase in metamorphic grade and injection of granitoid sheets.

D_2 Structures

Minor F_2 folds, which folded the S_1 foliation, are widely developed in the schists. They are generally upright to slightly overturned structures which plunge north-northeast and verge westward. Typically their limbs are closed and they have multiple rounded to subrounded hinges (Fig. 13b). Most of these folds are M-shaped, suggesting development in the axial regions of larger scale folds.

L_2 lineations are represented by locally abundant strong crenulations which plunge to the north at shallow to moderately steep angles, more or less

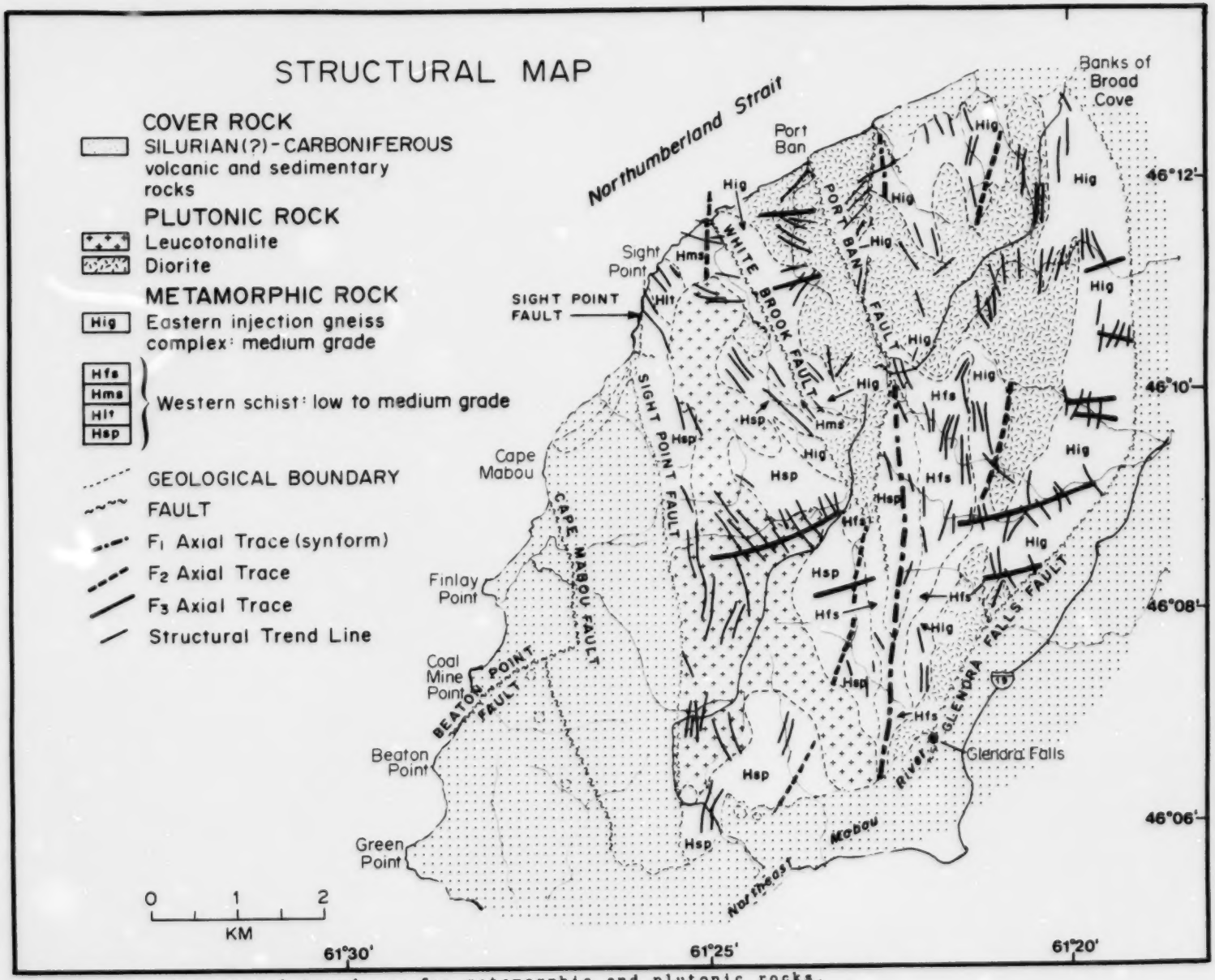


Figure 11. Structural trend map for metamorphic and plutonic rocks.

parallel with the F_2 fold axes (Fig. 12b). In the hinge areas of these folds, the crenulations define a crenulation cleavage which is mainly axial planar to the folds. However, in most exposures of the schists no distinct S_2 foliation is recognized, although in thin section a weak foliation is discerned oriented at low angles to the main S_1 foliation.

F

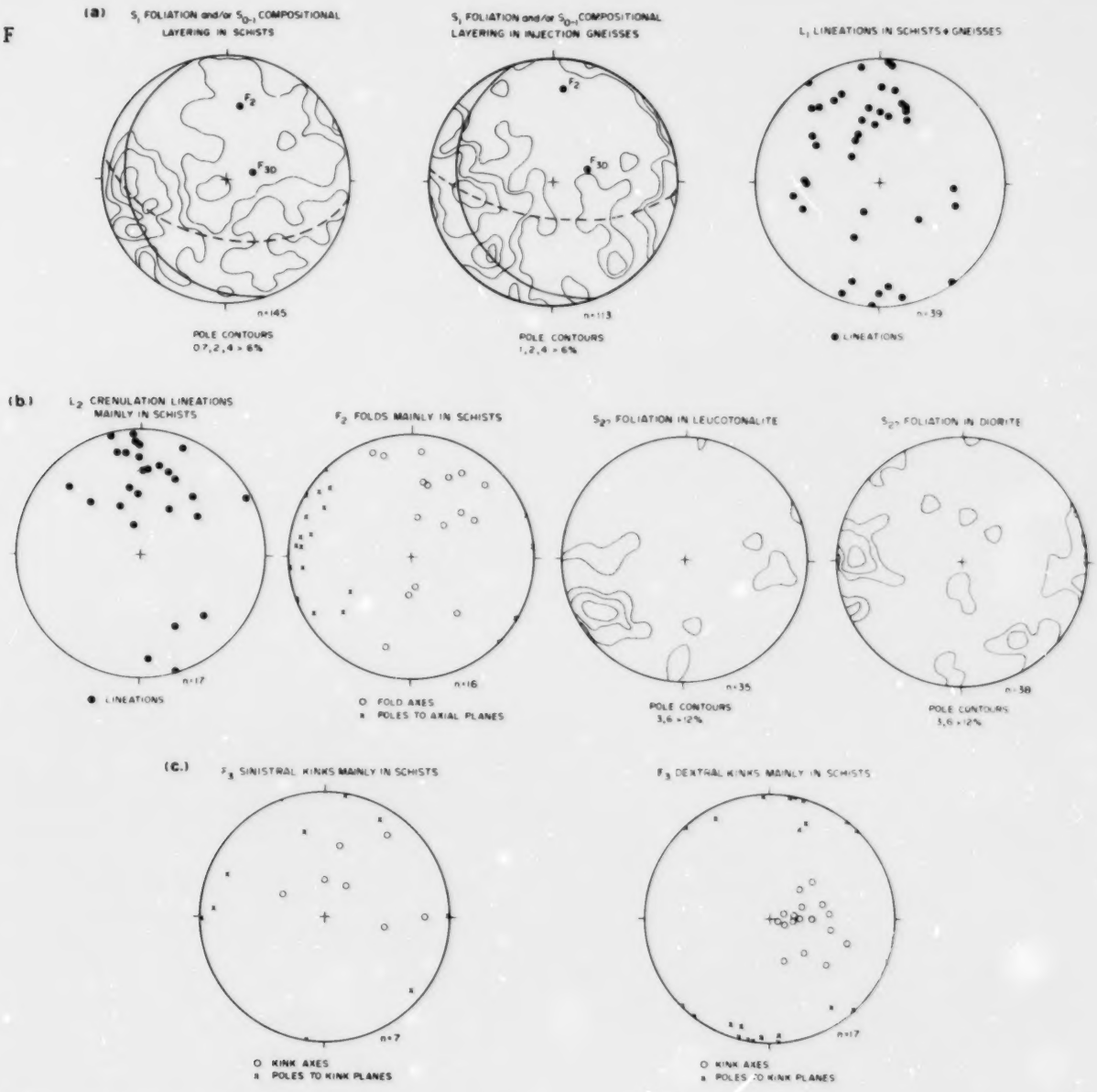


Figure 12. Structural data plots.
(a) S_1 foliation and(or) S_{0-1} compositional layering and L_1 lineations;
(b) L_2 lineations, F_2 folds, and S_2 foliations;
(c) F_3 kinks and joints in all rock types.
F_2 and F_3 are the average fold axes derived from the great-circle dispersion patterns of poles to S_1 foliations.

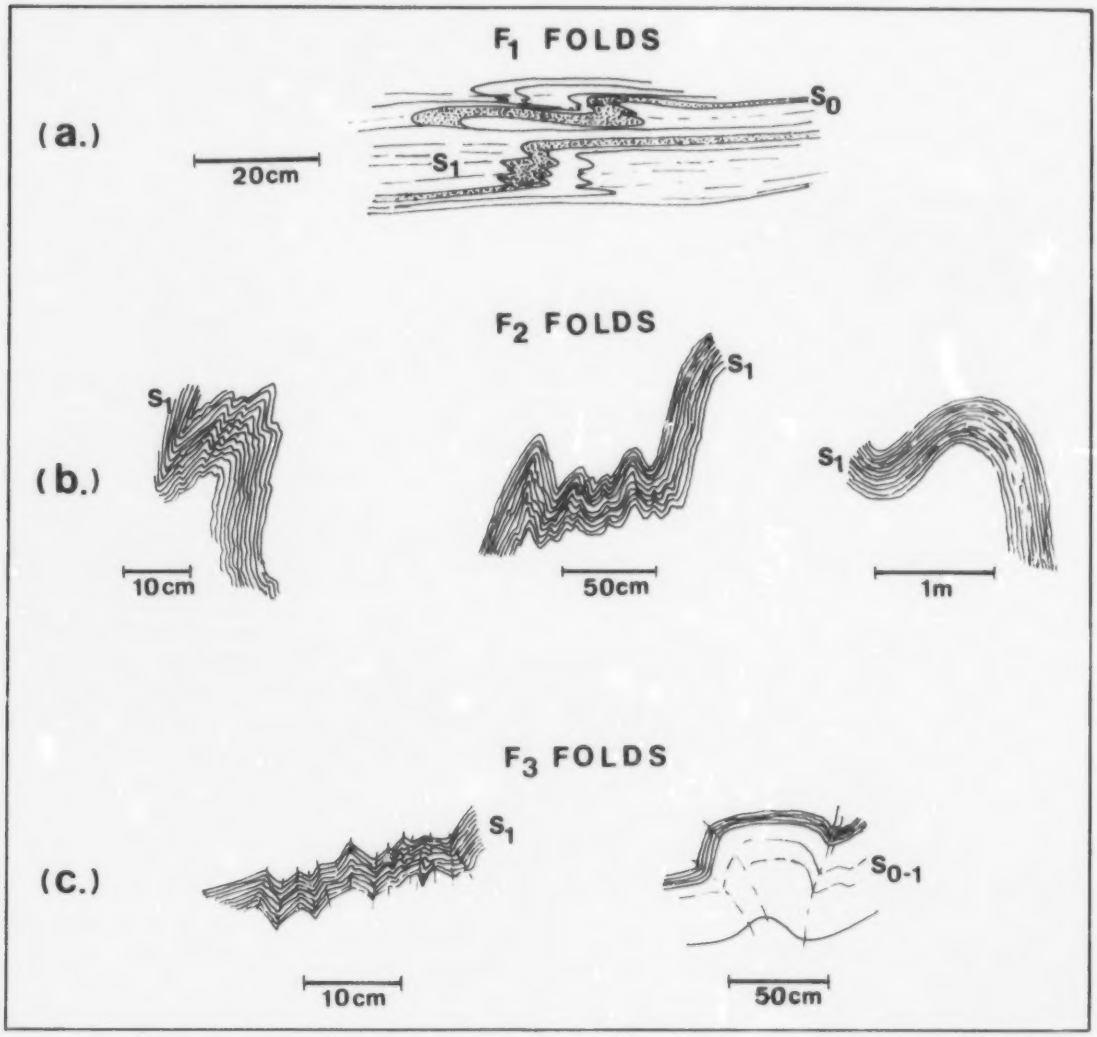


Figure 13. Examples of fold structures developed in metamorphic rocks.

Large scale D_2 fold structures are not well defined but several major upright folds trending north to north-northeast across the area can be inferred from the structural trend map (Fig. 11). These inferred folds are interrupted by faults and plutons.

D_3 Structures

D_3 minor structures are developed mainly in the schists and are dominated by a set of dextral kink bands and related kink folds which plunge steeply eastward (Figs. 12c and 13c). The kink planes are subvertical and strike eastward. These minor structures were rarely observed in other rock units but large scale folding about similarly oriented axes (as shown on the structural trend map) could have produced much of the scatter in orientations of the pervasive S_1 foliations observed in both the gneisses and schists (Fig. 12a) as well as of the S_2(?) foliation in the plutonic rocks (Fig. 12b). These large scale fold structures are inferred to be open, steeply plunging folds transecting the area at intervals of

approximately 1-2 km causing locally marked deviations in strike of the penetrative foliations (Fig. 11).

STRUCTURE OF THE PLUTONIC ROCKS

Protomylonitic foliations are developed in the leucotonalite and diorite plutons. In the leucotonalite body, the foliation strikes north-northwest and dips steeply to the east (Figs. 11 and 12b), whereas in the diorite bodies it strikes more northerly to north-northeasterly and dips steeply to the east (Figs. 11 and 12b). In both cases, the orientations are crudely concordant with foliation in the surrounding metamorphic rocks. However, the plutons truncate D_1 trends in the country rocks so their protomylonitic foliations are interpreted to be of D_2 age. The relatively weak D_2 fabric but common folding in the host metamorphic rocks possibly reflect their more ductile response to the same event. Common deviations toward more easterly trends are likely due to the effects of later shearing (D_3?).

SYNTHESIS

The main structure of the metamorphic rocks of the Mabou Highlands appears to be a large north-trending synform of D_1 age which plunges to the north-northwest (Table 11). This was intruded by leucotonalite and diorite plutons, before or during the subsequent phase of pervasive deformation (D_2). Superimposed on the synform are second order upright folds which plunge mainly north-northeast (see cross-section, map in pocket). These appear to have formed coplanar with the D_1 folding, resulting in slip along or close to the S_1-planes and hence transposition and(or) crenulation of the main foliation in the metamorphic rocks. This same event could possibly have produced the pervasive mylonitic foliation developed in the plutons. The absolute timing of the D_1 and D_2 events is not known, but they could represent continuous progressive deformation. Finally, third order cross folds, mainly steeply plunging, created warps and local east-west deflections in prevailing structural trends. This last event had the effect of north-south shortening which is reflected in the numerous kink-bands and kink folds developed in all the shistose units in the area.

YOUNGER FOLDING

The internal structure of the fault-bounded Silurian-Devonian(?) volcanic-sedimentary unit is not clear due to a combination of poor exposure and the predominance of massive volcanic flows and crystal tuff units. However, the rocks generally appear to dip moderately steeply to the northeast but there is also some evidence for east-southeastward folding from minor folds and localized slaty cleavage (Fig. 14a). No large scale folds have been identified, and it is not known what age this folding is or how it relates to the main north-south faults which define the unit. Any tilting between these faults which may have occurred subsequent to folding (see below) could have considerably reoriented the fold geometry.

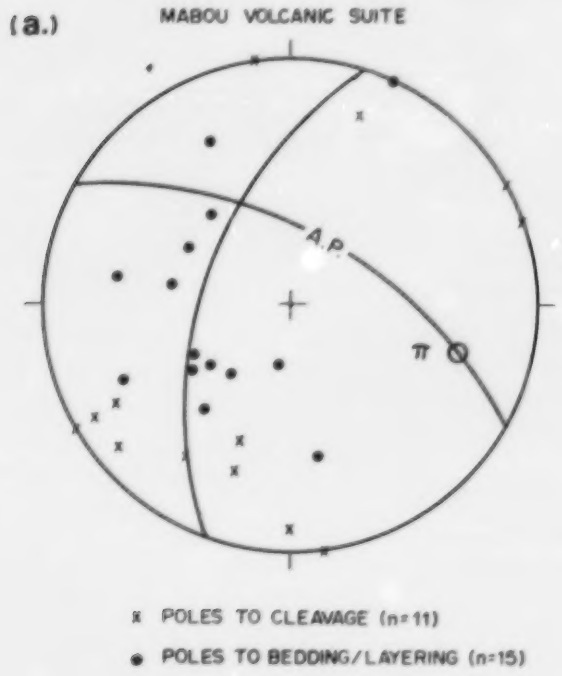
Rocks of the Horton Group are draped around three sides of the Mabou Highlands block, but generally dip away from it at about 30° to the south-southeast (Fig. 14b) toward the Mabou syncline, located south and southeast of the Mabou Highlands. Attitudes are complicated, as in the Silurian-Devonian(?) volcanic-sedimentary unit, by faulting and internal folding. Deviations occur adjacent to the major faults and where open upright folding about gently plunging west-southwest to southwest axes has occurred (Figs. 14b and 14c).

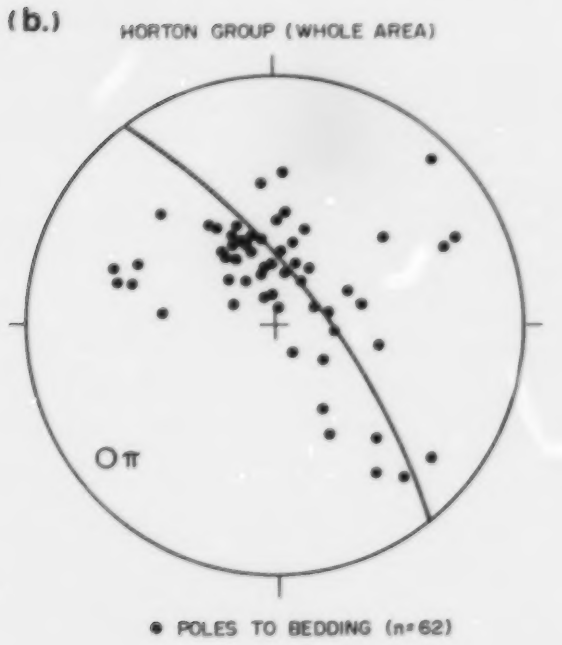
Rocks of the Windsor Group and the overlying Pennsylvanian unit have

Table 11. Summary of pre-Carboniferous deformational history associated with folding in the Mabou Highlands.

EVENT	FOLIATION	LINEATION	MINOR FOLDS	MAJOR FOLDS
D_1	Penetrative phyllosilicate foliation S_1 and(or) subparallel compositional layering S_{0-1}. Striking mainly N and dipping steeply E, although widely re-oriented by later folding.	Intersection lineation, rodding, mineral and tephra elongations. Variable but generally northerly plunge.	Rare rootless intrafolial folds.	1st order tight to isoclinal fold(s), suspected from apparent stratigraphic repetition.
D_2	Penetrative crenulation cleavage (schists), protomylonitic foliation (leucotonalite), and phyllosilicate foliation (granitoid rocks of injection complex). Striking mainly NNE, steeply dipping.	Crenulation lineation in schists, plunging mainly north at moderate angles.	Common upright, close, rounded to chevron folds in schists, plunging mainly north at moderate angles.	Localized 2nd order folds, mainly in schists.
D_3	Non-penetrative fracture cleavage(s), striking mainly ENE to ESE, with localized subparallel shear zones.	Ubiquitous kink axes.	(i) Common dextral kinks and kink folds plunging steeply east. (ii) Rare sinistral kinks.	Common 2nd order folds causing frequent deflections in strike.

overstepped the Horton Group rocks onto the older Silurian-Devonian(?) and Late Hadrynian-Paleozoic(?) rocks. These younger rocks generally dip northwest and southeast away from the Mabou Highlands block which therefore appears to occupy the core of a broad anticlinal structure, but this may be the result of supratenuous folding.





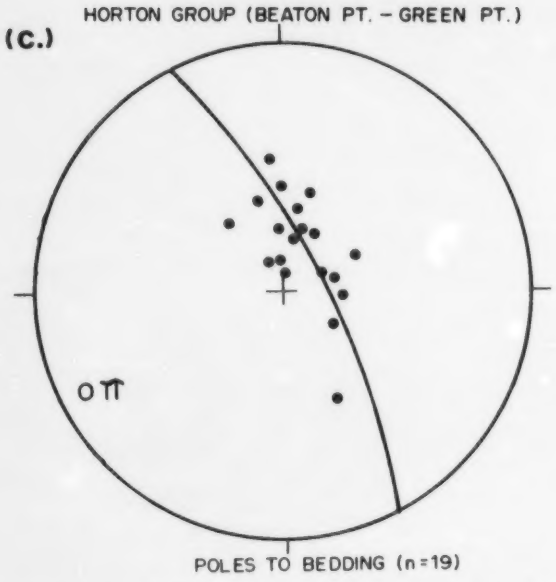


Figure 14. Structural data for Mabou volcanic-sedimentary suite and Horton Group. π is the average fold axis derived from the great-circle dispersion patterns.

FAULTING

The Mabou Highlands occur as an isolated horst block surrounded by a variety of sedimentary rocks of mainly Carboniferous age that are in nonconformable and faulted contact with the older crystalline rocks forming the core of the block.

North- and north-northwest-trending faults delimit and subdivide the horst block (Fig. 11). Considerable vertical displacement has ocurred across these faults, particularly on those lying east and west of Sight Point, which throw hundreds of metres down to the west, juxtaposing different rock sequences. The history of movements on these faults is not known except that some of the movement or throw is demonstrably older than the Windsor Group rocks (compare its "basement" east and west

of Cape Mabou; Fig. 2) and some is obviously post-Pennsylvanian. The distribution around the horst block of Carboniferous rocks, particularly those of the Horton Group and the over-stepping Windsor Group, suggests that the block already possessed positive relief in Mississippian time. It is also possible that some faulting accompanied eruption and deposition of the Silurian-Devonian(?) volcanic-sedimentary unit.

Other less important faults, which trend northeast to east-northeast, include the Beaton Point and Glenora Falls faults which downthrow Carboniferous rocks northwest and southeast, respectively. The Beaton Point fault also offsets the north-trending Cape Mabou fault and so these faults may be younger than the longer-lived north- and north-northwest-trending faults.

The Mabou Highlands block looks like a successively reactivated fault block now occupying the core of a broad anticlinal structure. It was perhaps initiated in the Silurian-Devonian and may have been a positive topographic feature in Early Mississippian time during deposition of the Horton Group (the abundance of conglomerates suggests that this was the case). Certainly it became so prior to deposition of the Windsor Group and was reactivated during the folding which affected all Mississippian and Pennsylvanian rocks which flank the horst block.

METAMORPHISM

INTRODUCTION

The pattern of metamorphism in the Mabou Highlands appears deceptively simple, with low grade schists to the west and medium grade gneisses to the east (Fig. 15). However, complications exist because of grade juxtaposition across north- to north-northwest-trending faults, rapid variation in lithology across strike from west to east (and hence compositional control on appearance/non-appearance of index minerals) and masking toward the east by wholesale injection of granitoid sheets.

METAMORPHIC FABRIC

The schists are typically fine grained, highly schistose rocks and many have small porphyroblasts and(or) porphyroclasts which range in size from 0.5-2.0 mm. The strong S_1 foliation is well defined by aligned phyllosilicates but is also emphasized by fine compositional layering (S_{0-1}), and intense deformation of quartz into ribbon-shaped grains (seen in thin section) showing only partial recovery in the form of subgrain development. This layering is intensely crumpled into F_2 microfolds and commonly displays related crenulation or strain-slip cleavage (S_2) oriented at approximately 30-40° to S_1. Overprinting S_1 are euhedral porphyroblasts of chloritoid, actinolite, staurolite and garnet which appear either randomly oriented or weakly aligned parallel to S_2. Both garnet and staurolite porphyroblasts commonly contain S_1 inclusion trails, some of which are sigmoidal in form suggesting that growth of these porphyroblasts was in part syntectonic with F_2 crenulation development. These euhedral porphyroblasts contrast strongly with the highly deformed quartz and plagioclase porphyroclasts which are present in many of the schists of tuffaceous origin.

Thus, timing of the metamorphic peak, as represented by porphyroblastic mineral growth, apparently post-dated development of the S_1 foliation and probably pre-dated or slightly overlapped the D_2 deformation.

The gneisses of the injection complex are typically fine- to medium-grained rocks displaying thin gneissic (segregation?) layering. In some

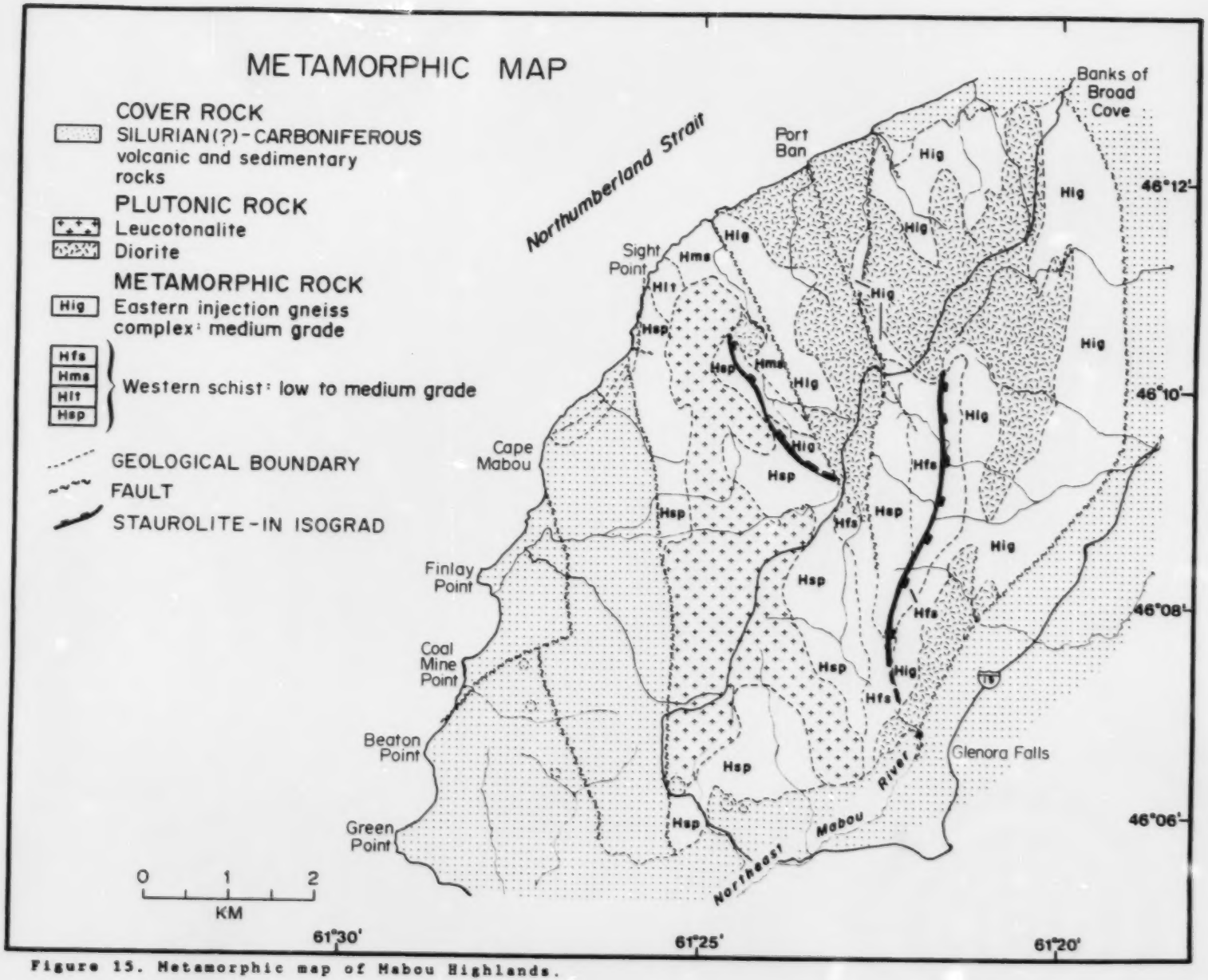


Figure 15. Metamorphic map of Mabou Highlands.

places, this layering is emphasized by grain size variations (alternating fine- and medium-grained layers), intense deformation of quartz and feldspar into "ribbons" and porphyroclastic augen characteristic of mylonitized flaser gneisses, and thin felsic gneiss layers (0.5-10 cm). Some of these felsic layers may be of primary or segregation origin but others are probably thin aplite sheets injected concordantly with the S_1 foliation.

Locally, the gneisses contain coarse feldspar porphyroblasts (up to 5 mm) which formed as a result of partial metasomatism and resemble the porphyritic granodiorite sheets which, together with granite, syenogranite and aplite, are common components of the gneissic complex. Most of the gneisses are biotite-hornblende-quartz-feldspar gneisses and amphibolites with chiefly granoblastic textures, and hence are relatively competent rocks which do not show the crumpling and cleavages exhibited by the schists. Presumably equivalent late superimposed structures in the gneisses include: ribbon quartz fabrics, rare crude strain-slip cleavage and thin sericitic-chloritic shear zones. No truly pelitic gneisses, equivalent to the porphyroblastic garnet-staurolite schists, were observed, although the gneisses are believed to be higher grade equivalents of the various schist units.

METAMORPHIC GRADE

The only isograd which can be defined in the map area is the staurolite-in isograd (Fig. 15) which can be recognized in both the laminated and banded schist units. Most of the schists are below staurolite grade and the only porphyroblasts recognized in these lower grade schists are chloritoid, garnet and actinolite but occurrences of these porphyroblasts are too restricted to permit definition of appropriate isograds.

The lower grade schists are generally characterized by the presence of biotite ± chlorite or garnet. The more pelitic of these schists commonly also contain graphitic material, whereas the more tuffaceous and volcanic schists also contain epidote, actinolite/hornblende and calcite. Such assemblages are typical of upper greenschist facies and of the greenschist-amphibolite transition.

In the medium-grade schists primary chlorite is typically absent and garnet + staurolite + muscovite ± biotite is the common assemblage in the pelitic schists whereas hornblende + epidote + biotite + calcite + sphene is the common assemblage in the tuffaceous-volcanic schists, in addition to quartz and plagioclase (An_{30}). Such assemblages are more typical of amphibolite facies (Winkler, 1976).

Comparing the low grade and medium grade pelitic assemblages, it seems likely that the staurolite-in reaction can be represented by:

garnet + chlorite + muscovite $\rightleftharpoons$ staurolite + biotite

which could yield the medium-grade assemblage of garnet-muscovite-staurolite-biotite.

The gneisses of the injection complex are typically amphibolitic to quartzofeldspathic. From the absence of primary chlorite, together with the common assemblage of epidote + biotite + hornblende + andesine (An_{27-45}), these gneisses can be considered medium grade rocks metamorphosed to amphibolite facies (after Winkler, 1976, p. 169).

Thus it seems probable that the complete sequence from schist through to gneiss represents progressive metamorphism from greenschist facies in

the west to amphibolite facies in the east.

The fact that leucotonalite intruded the low grade schists, whereas diorite invaded only medium grade gneisses and schists (above staurolite grade) could be fortuitous, or it could reflect, given the major north- and north-northwest-trending faults in the area, erosion to different levels of a large composite pluton. Time of emplacement of these plutons relative to the peak of metamorphism is not known directly, but the pervasive foliations in the plutons suggest that they were emplaced prior to or during D_2 deformation, i.e. following the metamorphic peak. Certainly this deformation continued after pluton emplacement (and the metamorphic peak?) as retrograde alteration to sericite, chlorite, calcite and hematite is widespread, especially in the leucotonalite body.

ECONOMIC GEOLOGY

INTRODUCTION

In addition to the coal seams in the flanking Pennsylvanian strata, a few occurrences of economic minerals in the Mabou Highlands are significant enough to have been explored via geochemical stream-sediment and soil sampling, geophysical surveys, and limited diamond drilling. The main types of occurrences and the environments in which they occur include:

(1) quartz vein and fracture-related galena and sphalerite in schistose rocks of the western Highlands,
(2) stratabound disseminated galena in basal limestone of the Windsor Group,
(3) barite replacement of Windsor limestones above the Horton-Windsor contact and
(4) stratabound disseminated pyrite in Pennsylvanian sandstones.

QUARTZ VEIN AND FRACTURE-RELATED GALENA AND SPHALERITE

Following a report by Norman (1935, p.17) of float sulphide mineralization in the upper drainage area of the Mabou River and the discovery of a large geochemical anomaly in the watershed area to the west (Sogemines Development Company Limited, 1967), occurrences of lead-zinc mineralization were found in the upper drainage systems of both White Brook and Northeast Mabou River. Both occurrences are located in approximately similar stratigraphic positions close to the eastern contact of the main laminated phyllite-schist units and the metavolcanic units and not far from the margin of the leucotonalite pluton (Fig. 16).

A. White Brook Occurrence

In the White Brook area, Cuvier Mines Limited (1973) defined northeast-trending, coincident, strong lead and zinc anomalies (up to 2000 ppm) located above schists lying between the leucotonalite pluton and an adjacent diorite stock. Five diamond-drill holes were completed but only two intersected mineralization. The host rocks were mainly grey-green and blue-grey schist, andesite (metabasalt?) and silicified hornfels cut by granite and(or) diorite sheets. Pyrite, pyrrhotite and sphalerite were the main sulphides and these were associated with quartz veins and stringers and with fractures. The mineralization was sparse and no assay values were reported (Cuvier Mines Limited, 1973).

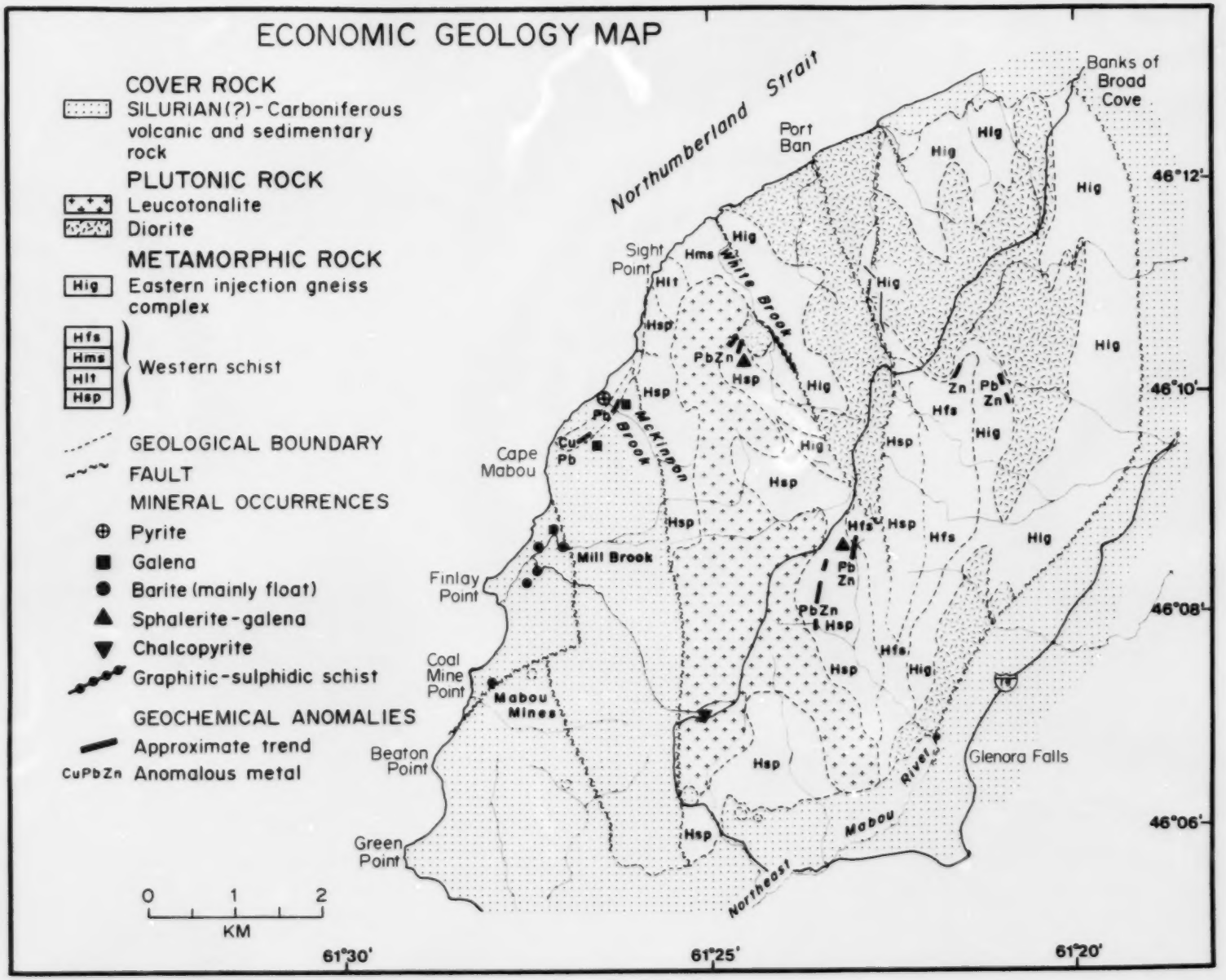


Figure 16. Mineral occurrence map of the Mabou Highlands.

B. Northeast Mabou River Occurrence

Following the discovery of base metal stream sediment anomalies (McNabb et al., 1976) in the upper drainage of the Northeast Mabou River, Noranda Exploration Limited defined geochemically anomalous areas (Leahey, 1978, 1979) associated with laminated chloritic schists and with leucotonalite and diorite plutons flanking the schists.

In the schists, north-trending, coincident lead-zinc soil anomalies were defined and rusty gossanous zones found. Two shallow exploration holes were drilled, followed by one deep diamond-drill hole (140 m) which confirmed the existence of sulphide mineralization in the chloritic schists and associated felsic to intermediate metatuffs. Very minor disseminated galena, sphalerite, pyrrhotite and pyrite were noted throughout much of the core. The best mineralization occurred between 90 and 95 m and averaged 1% combined lead and zinc. Within this, a 1.5 m section assayed 1.9% lead and zinc (Graves, 1981). Poor recovery to 76 m was thought to represent the presence of a fault or fracture zone.

About 2 km southwest of the main occurrence, weak lead and zinc soil anomalies (some of which were coincident) were found associated with strongly schistose zones within the leucotonalite pluton but no surface mineralization was reported and no exploratory drilling carried out (Leahey, 1979). However, disseminated pyrite and chalcopyrite in dark, chlorite-altered leucotonalite have been found in a shallow pit close to the road in this area (Fig. 16).

Other weak soil anomalies which were found about 2 km north-northeast of the main occurrence include coincident lead-zinc anomalies over banded schists within which were found scattered pyrite occurrences, and scattered weak zinc anomalies (over staurolite-bearing schists) adjacent to the diorite pluton there.

It is likely that the sulphide occurrences in the upper part of Northeast Mabou River and in White Brook are related. Both occur in low grade laminated chloritic schists/phyllites close to contacts with metavolcanic units between the leucotonalite and the diorite plutons (Fig. 16). Although the graphitic-sulphidic schist layer(s) occurring in the metavolcanic unit suggests that stratabound or stratiform mineralization does occur, the drilled occurrences have the character of epigenetic vein and fracture fillings and related disseminations. The role of the leucotonalite in the genesis of this mineralization is not clear. Although coincident copper-lead-zinc anomalies have been found locally over the southwestern part of the pluton, the only mineralization actually found there is copper-dominant. Perhaps there was large scale zoning with lead-zinc mineralization having been localized in the metasedimentary-metavolcanic country rocks.

STRATABOUND DISSEMINATED GALENA

Minor stratabound lead mineralization has been reported (Coté, 1966; Spat, 1967; Wright, 1971) from basal limestone of the Windsor Group in the McKinnon Brook area in the northwestern part of the Highlands (Fig. 16). The mineralization, which has been found at three locations, consists primarily of finely disseminated galena, locally with rare sphalerite and chalcopyrite (associated with malachite/azurite staining). The best occurrence is in McKinnon Brook where disseminated galena in the basal grey crystalline limestone grades 0.3% Pb over a 1.5 m thickness. A broad lead soil anomaly extends 600 m to the southwest paralleling the base of the Windsor

Group to where it peaks at about 3000 ppm Pb and overlaps a local copper anomaly (peak at 320 ppm). The other two occurrences of visible mineralization are in this general area.

BARITE

Float blocks of barite, which has apparently replaced Windsor Group limestone, occur along a 100 m stretch of Mill Brook at the western edge of the Mabou Highlands close to a local Windsor-Horton contact and to a major faulted contact with the Silurian-Devonian(?) volcanic-sedimentary sequence. Some of the blocks also contain chalcopyrite. Hudgins (1971) proposed that the source of the barite was a pipe-like mass associated with a west-plunging fold structure and speculated that a Walton-type base metal and barite deposit could be present. Three exploratory holes were drilled but only one reached bedrock and no barite was found (IMC Drilling Mud Incorporated, 1972). Subsequent trenching of the banks of Mill Brook in the vicinity of the float blocks failed to reveal any *in-situ* barite (Barret, 1981).

Other float barite occurrences have been found farther west and southwest along Mill Brook near the Horton-Windsor contact (Wright, 1971). *In situ* barite occurrences have been found in brecciated limestone near the base of the Windsor strata at Finlay Point on the coast (McBeath, 1972) and farther south at Mabou Mines where diamond-drilling located the source of the float barite as replacements of limestone over a thickness of 5 m above the Horton-Windsor contact (Felderhof, 1978).

STRATABOUND DISSEMINATED PYRITE

In McKinnon Brook, downstream from the galena occurrence in the basal Windsor limestone, a 100 m wide zone of disseminated pyrite occurs in grey-green sandstones with associated pebble conglomerate lenses just above the Mississippian-Pennsylvanian contact (Spat, 1967; Wright, 1971). The pyrite is fine grained and forms bedding-parallel disseminations and small nodular concentrations that are closely associated with carbonized plant fragments. Rare chalcopyrite and sphalerite locally occur with the pyrite.

EXPLORATION POTENTIAL

Perhaps the most obvious exploration target in the Mabou Highlands is polymetallic sulphides associated with the metasedimentary and metavolcanic rocks east of the leucotonalite pluton. The mineralogy and textures of the two drilled lead-zinc occurrences have been described only superficially, yet some potential for silver, or even gold, may exist (Norman (1935) reported float tetrahedrite from the same general area). The genesis of the known occurrences is not clear. Exhalative volcano-sedimentary occurrences cannot be ruled out as graphitic-pyritic schists were noted locally in the mafic schist and amphibolite unit and the metavolcanic rocks exhibit geochemical features indicative of spreading within an arc environment.

DISCUSSION

Two groups of metamorphic rocks have been recognized in the Mabou Highlands, a schist sequence in the west and an injection gneiss complex in the east. Metamorphic grade increases from greenschist to amphibolite facies from west to east and the only structural breaks between the two groups are younger high-angle faults. Hence both groups are assumed to belong to the same volcanic-sedimentary precursor. The schists have been intruded by a leucotonalite pluton and a small diorite body, whereas the

gneisses have been intruded by several related (subjacent?) diorite plutons and by a myriad of granitoid sheets which have created extensive injection migmatites.

The volcanic-sedimentary metamorphic rocks of the Mabou Highlands closely resemble volcanic-sedimentary sequences found in various parts of the Cape Breton Highlands (Macdonald and Smith, 1980; Jamieson, 1981; Jamieson and Craw, 1983; Fig. 1). In particular, they show many similarities in lithological association, deformational history, metamorphic grade, and geochemistry (where this has been determined). Characteristic volcanic components are: (1) one or more mafic volcanic sequence(s) comprising flows and tuffs with gabbroic sills, (2) lapilli tuffs of intermediate composition, (3) alternating felsic and intermediate fine grained tuffs and (4) thin rhyolite flows(?). Associated with these and interbedded on different scales are a variety of sedimentary units, including thinly bedded pelites, semi-pelites and psammites, together with rare sulphidic pelites and carbonate layers. Virtually identical packages have been described at Cape North (Macdonald and Smith, 1980) and in the Cheticamp and Crowdis Mountain-Middle River areas (Jamieson and Craw, 1983; Jamieson and Doucet, 1983), although the relative abundances of the components differ.

The rocks, particularly the lower grade schistose units, clearly display the effects of polyphase deformation. Superimposed on the pervasive phyllitic schistosity (S_1), at low to moderate angles to it, is a crenulation cleavage (S_2) within which late porphyroblastic mineral growth has occurred. Whereas early tight to isoclinal folds (F_1) are rare, later upright F_2 folds are a common feature. This refolding was nearly coaxial with the F_1 folding, based on orientations of rare F_1 minor folds and widespread strong L_1 intersection lineations. Proto-mylonitic foliation developed in the plutonic rocks and to some extent in the gneissic rocks may also be of this D_2 age. Transecting these structures at high angles are several sets of kink bands, larger kink folds (F_3), and related fracture cleavages; easterly trends are dominant. Similar structural elements have also been recognized in the volcanic-sedimentary sequences at Cape North (Macdonald and Smith, 1980) and Crowdis Mountain-Middle River (Jamieson and Doucet, 1983; Doucet, 1983).

General metamorphic features are also comparable between the Mabou Highlands and Cape Breton Highlands, with the volcanic-sedimentary metamorphic rocks commonly displaying textural and mineralogical features indicative of a late-tectonic (D_2) transition from greenschist into amphibolite facies. At the highest grades attained, the rocks apparently lost their phyllitic and schistose character and became increasingly gneissic and hence are difficult to correlate across grade (Macdonald and Smith, 1980; Jamieson and Doucet, 1983; Craw, 1984). Polarity of the grade increase in the Mabou Highlands is from west to east, consistent with that observed in the western Cape Breton Highlands (Currie, 1982; Craw, 1984). In general, grade increases toward the core of the Cape Breton Highlands.

Only limited geochemical data from the volcanic flow units in the volcanic-sedimentary sequences are as yet available but these indicate that volcanic rocks from the Mabou Highlands are virtually identical to those from the Money Point Group at Cape North (Fig. 3b-h). The flows apparently resemble an island-arc tholeiitic suite but show some geochemical features which are transitional between island-arc tholeiites and ocean-floor basalts, perhaps reflecting a component of local spreading, as in a back-arc or intra-arc environment. These tentative conclusions are consistent with the

tectonic setting indicated by the dioritic-leucotonalitic plutons in the Mabou Highlands, suggesting that (excepting the inferred Silurian-Devonian and younger units) volcanism-sedimentation, metamorphism, deformation, and plutonism in the Mabou Highlands may have been part of a single orogenic event.

The ages of these metamorphosed volcanic-sedimentary and associated late-tectonic plutonic rocks in the Mabou Highlands and in the Cape Breton Highlands are not well constrained. The volcanic-sedimentary rocks of the Cape Breton Highlands are commonly inferred to be Late Precambrian in age (Macdonald and Smith, 1980; Jamieson and Doucet, 1983; Jamieson and Craw, 1983; Barr et al., 1985) but they may be much younger, perhaps Ordovician to Silurian (Currie, 1982; Jamieson et al., 1986).

The inferred Silurian-Devonian volcanic-sedimentary unit of the Mabou Highlands is interpreted to represent sedimentation and volcanism in local, late orogenic rift basins. Major faulting was probably associated with this stage in the evolution of the Mabou Highlands. Faulting continued during and after deposition of younger sediments around the periphery of the Highlands.

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The authors wish to point out that this report was written prior to 1986, and hence it was impossible to incorporate subsequent major developments in the understanding of the geology of the Cape Breton Highlands.

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APPENDIX A

PETROGRAPHIC DESCRIPTIONS OF VOLCANIC AND METAVOLCANIC ROCKS

KEY TO ABBREVIATIONS USED IN PETROGRAPHIC TABLES FOR VOLCANIC AND METAVOLCANIC ROCKS

Qz	Quartz
Ksp	K-feldspar
Plg	Plagioclase
Pyx	Pyroxene
Amp	Amphibole
Bio	Biotite
Mus	Muscovite
Chl	Chlorite
Ep	Epidote
Cc	Calcite
Opq	Opagque phase(s)
Hem	Hematite
Lcx	Leucoxene
Sph	Sphene

tr = trace amounts <1%

ESTIMATED MODAL MINERALOGY OF SILURIAN-DEVONIAN(?) VOLCANIC ROCKS* WHICH HAVE BEEN CHEMICALLY ANALYZED

	Qz	Ksp	Plg*	Pyx	Amp	Bio	Mus	Chl	Ep	Cc	Opq	Hem	Lcx	Sph	*Plag Compn.	Texture
MAFIC FLOWS:																
1050	-	-	75	-	-	-	-	7	10	6	2	tr	-	-	An_{27-32}	Hiatal porphyritic, flow aligned plagioclase laths
1054	-	-	65	-	-	-	-	15	10	7	2	-	-	1	An_{24}	Fine grained intergranular
1056	-	-	75	-	-	-	-	-	-	10	5	10	-	-	An_{27}	Seriate porphyritic, felty groundmass
1541	-	-	70	-	-	-	-	15	-	10	-	5	-	-	An_{33}	Fine grained, pilotaxitic
1624	-	-	40	-	-	-	-	17	10	30	1	-	2	-	An_{28}	Fine grained, schistose
1671	-	-	55	-	-	-	-	15	3	20	-	7	-	-	An_{30}	Fine grained, sub-porphyritic, felty groundmass
1672	-	-	50	-	-	-	-	10	14	22	1	-	-	3	An_{27}	Fine grained, pilotaxitic
TUFFS:																
1131	1	-	35	-	-	-	5	15	30	10	-	4	-	-	An_{27}	Porphyroclastic feldspar
1154	35	-	55	-	-	-	-	3	-	5	1	-	-	1	An_{8}	Porphyroclastic quartz < feldspar, rare lithic fragment
1669	5	-	65	-	-	-	-	3	-	25	2	-	-	-	An_{33}	Schistose porphyroclastic

*Sample locations are shown on map in pocket.

ESTIMATED MODAL MINERALOGY OF METAVOLCANIC ROCKS* WHICH HAVE BEEN CHEMICALLY ANALYZED

	Qz	Ksp	Plg*	Pyx	Amp	Bio	Mus	Chl	Ep	Cc	Opq	Hem	Lcx	Sph	*Plag Compn.	Texture
MAFIC SCHISTS:																
1035	10	-	35	-	35	4	-	-	15	-	1	-	-	-	An_{33}	Porphyroclastic, fine grained lepidoblastic-granoblastic schistose
1094	5	-	45	-	30	13	-	-	5	-	2	-	-	-	?	Lepidoblastic-granoblastic
1616	12	-	33	-	38	8	-	-	-	2	7	-	-	-	An_{32}	Medium grained granoblastic
1617	10	-	40	-	38	6	-	2	-	2	2	-	-	-	?	Fine grained lepidoblastic-granoblastic schistose
1619	6	-	30	-	47	10	-	2	-	1	3	-	-	1	?	Fine grained, lepidoblastic-granoblastic schistose
1700	3	-	55	-	22	8	-	-	2	8	2	-	-	-	An_{32}	Porphyroblastic, lepidoblastic schistose
1703	-	-	30	-	35	2	-	25	2	3	1	-	-	2	An_{28}	Porphyroblastic, 2 amphiboles present
1704	3	-	60	-	-	20	-	10	-	5	2	-	-	-	An_{12}	Porphyroclastic, fine to medium grained lepidoblastic-granoblastic
1708	-	-	60	-	20	-	-	8	10	-	-	-	2	-	An_{33}	Medium grained porphyroclastic-granoblastic
FELSIC SCHISTS:																
1574	55	-	15	-	-	15	-	5	10	-	-	-	-	-	?	Fine grained lepidoblastic-granoblastic schistose
1618	30	-	45	-	-	6	-	4	12	2	1	-	-	-	An_{8}	Slightly porphyroclastic, fine grained schistose
1702	35	-	35	-	-	3	16	-	-	10	1	-	-	-	An_{6}	Porphyroclastic, lepidoblastic-granoblastic crenulated schistose
1705	50	-	40	-	-	5	tr	-	3	-	2	-	-	-	An_{8}	Porphyroclastic, fine grained schistose
1706	25	5	40	-	-	-	15	-	8	7	-	-	-	-	An_{6}	Porphyroclastic, lepidoblastic-granoblastic schistose

*Sample locations are shown on map in pocket.

APPENDIX B

PETROGRAPHIC DESCRIPTIONS OF PLUTONIC ROCKS

KEY TO ABBREVIATIONS AND SYMBOLS USED IN PETROGRAPHIC TABLES FOR PLUTONIC ROCKS

Major Minerals

Q Quartz
Ks K-feldspar
Pl Plagioclase
Bi Biotite
Hb Hornblende
Py Pyroxene

Accessory Minerals

O Opaques
A Apatite
S Sphene
Z Zircon
Symbols:
O = normal abundance
X = more abundant than usual

Rock name follows Streckeisen (1976)

Ks Column

Identity of K-feldspar (based on 2V, twinning)

M Microcline
O Orthoclase
P Perthite

Plagioclase Composition Column

Gives estimated maximum An content (determined by Michel-Levy, combined Carlsbad-albite, or perpendicular to "a" crystallographic axis method).

Grain Size, Texture Column

f.g. fine grained
m.g. medium grained
c.g. coarse grained

Gran. Equigranular
Inequig. Inequigranular
Porph. Porphyritic
Intergran. Intergranular

Allot. Allotriomorphic
Hyp. Hypidiomorphic

Alteration

s = slight, m = moderate, i = intense

Ac Actinolite
C Carbonate
Cl Chlorite (±secondary sphene, rutile)
E Epidote
H Hematite
S Saussurite (includes f.g. albite, carbonate, sericite, clay, epidote, etc., replacing plagioclase)
Sc Sericite

MODAL MINERALOGY OF ANALYZED PLUTONIC ROCKS

Sample Number	Rock Name	Major Minerals Q	Ks	Pl	Bi	Hb	Py	Ks	Plag Comp (%An)	Accessories O	A	S	Z	Grain Size, Texture	Alteration Ac	C	Cl	E	H	S	Sc	Comments
1007	Quartz diorite	5	1	58	20	15	1	-	-	O	O	O	O	m.g. - c.g. allot. gran.	-	-	s	-	-	s	s	Cataclastic texture
1020	Quartz diorite	4	1	62	13	20	-	-	~30	O	O	X	O	f.g. - m.g. allot. inequig.	-	-	s	-	-	s	s	Strongly zoned subporphyritic plagioclase
1038	Quartz diorite	5	-	55	15	25	-	-	~30	O	O	X	O	m.g. allot. gran.	-	-	s	-	-	s	s	Weakly sheared; zoned plagioclase
1039	Quartz diorite	3	-	54	20	20	3	-	~30	O	O	O	-	m.g. allot. gran.	-	-	s	-	-	m	s	Relict orthopyroxene
1077	Quartz diorite	3	-	53	21	23	-	-	~35	O	O	O	O	m.g. - c.g. allot. gran.	-	-	s	-	-	m	s	Weakly cataclased
1114	Quartz diorite	8	-	50	22	20	-	-	~30	O	O	O	O	m.g. sheared	-	-	s	-	-	m	s	Sheared/cataclased; Q and Pl augen
1144	Quartz diorite	2	-	52	20	26	-	-	-	O	X	O	O	m.g. allot. inequig.	-	-	s	-	-	m	m	Foliated, sheared; zoned plagioclase
1527	Quartz diorite	4	-	52	17	27	-	-	~30	O	X	O	O	m.g. allot. gran.	s	-	s	-	-	s	s	Zoned plagioclase
1582	Quartz diorite	4	-	63	18	15	-	-	-	O	X	O	O	m.g. allot. gran.	m	m	m	-	-	m	s	Carbonate veining
1607	Quartz diorite	7	-	55	16	22	-	-	~40	O	O	O	O	f.g. allot. gran.	-	-	s	-	-	s	s	Recrystallized (?)
1609	Quartz diorite	4	-	55	16	25	-	-	-	O	X	X	O	m.g. - c.g. allot. gran.	s	-	s	-	-	s	s	Foliated; polycrystalline interstitial quartz
1611	Quartz diorite	4	-	62	18	16	-	-		O	O	X	O	f.g. allot. gran.	m	m	s	-	-	s	s	Foliated; cataclased
1064	Leucotonalite	25	-	50	15	?	-	-	~30	O	O	?	?	c.g. sheared	-	-	m	-	-	m	m	Sheared; altered mafic minerals = 10%
1067	Leucotonalite	20	-	60	?	20	-	-	?	O	O	?	?	m.g. - c.g. allot. gran.	-	-	m	m	m	m	-	Interstitial quartz
1071	Leucotonalite	22	-	55	-	?	-	-	?	O	?	?	?	c.g. sheared	-	-	i	m	-	i	i	Altered mafic minerals 23% Sheared and cataclased
1128	Leucotonalite	20	-	72	-	8	-	-	?	O	O	X	O	c.g. sheared	-	-	i	m	-	i	-	Polycrystalline interstitial quartz
1129	Leucotonalite	22	-	68	-	10	-	-	?	O	O	?	?	c.g. allot. gran.	-	-	i	m	-	i	-	Polycrystalline interstitial quartz
1661	Leucotonalite	18	-	65	-	17			~30	O	?	?	?	m.g. cataclastic	-	-	i	i	-	m	-	Sheared and cataclased
1500	Granodiorite	12	28	43	5	12	-	MP	~25	O	O	X	O	c.g. cataclastic	-	-	s	-	-	s	s	Cataclased; feldspar augen
1504	Granodiorite	12	30	38	8	12	-	MP	?	O	O	X	O	c.g. cataclastic	-	-	s	-	-	m	s	Sheared; zoned plagioclase
1615	Granodiorite	15	30	43	12	-	-	MP	~20	O	O	X	O	c.g. allot. inequig.	-	-	s	-	-	m	s	Feldspar augen; zoned plagioclase
1108	Granite	18	33	41	8	-	-	MP	~20	O	O	X	O	m.g. cataclastic	-	-	m	-	s	m	m	Sheared/cataclased; minor myrmekite
1509	Granite	20	35	38	7	-	-	M	~20	O	O	O	O	m.g. cataclastic	-	-	m	-	s	m	s	Sheared/cataclased; minor myrmekite
1602	Granite	20	32	40	8	-	-	M	~20	O	O	O	O	m.g. cataclastic	-	-	m	-	m	m	s	Sheared/cataclased; abundant myrmekite
1612	Granite	26	30	38	6	-	-	M	?	O	O	O	?	m.g. cataclastic	-	-	m	-	s	m	-	Foliated/cataclased
1626	Aplitic Granite	30	32	36	2	-	-	M	~15	O	?	?	O	f.g. allot. inequig.	-	-	s	-	-	s	s	Aplitic, subporphyritic
1515	Aplitic Granite	28	37	33	2	-	-	M	?	O	?	?	O	m.g. sheared	-	-	m	-	s	m	s	Foliated, sheared

*Sample locations are shown on map in pocket.

APPENDIX C

ANALYTICAL METHODS

WHOLE-ROCK ANALYSES

SAMPLE PREPARATION

Powdered samples for analysis were prepared at the Laboratory for the Investigation of Minerals (CLIM), Technical University of Nova Scotia, Halifax. Each large (1 - 2 kg) sample was broken with a sledge hammer and fresh fragments were handpicked, avoiding weathered exterior surfaces, veins, and xenoliths. The fresh material was then further crushed in a hardened steel jaw-crusher, and then split to produce a 100 g sample. This was then powdered to -100 mesh in a shatterbox using a hardened steel container and puck.

ANALYSES

Major element analyses were done in the Department of Geology, Acadia University, Wolfville, by atomic absorption spectrometry (elements Si, Ti, Al, Fe, Mn, Mg and Ca) and flame photometry (Na, K). Methods are described in more detail by Fox (1983). Loss on ignition was determined as percentage weight loss after heating in a muffle furnace for one hour at 1000°C.

Analyses for P, ferrous iron, and most minor and trace elements (Ba, Rb, Sr, Li, F, B, Be, Mo, Cu, Pb, Zn, Ni, Cr, Co, Y, Nb, Zr, Sn, W, U, Th and S in Tables 5, 7, 9 and 10) were done by CLIM Laboratories (Halifax) using the methods described by Barr et al. (1982). Minor and trace element data in Table 1 were done by X-Ray Fluorescence at the Regional XRF Facility, St. Mary's University, Halifax (analyst K. Cameron).

Analyses performed at Acadia University were done in duplicate, using international reference samples AGV-1, BCR-1, G-2, GSP-2, JB-1 and JG-1 (Abbey, 1977) as standards. Duplicate results were always within 10% (and generally much closer than 10%) of one another. At CLIM Laboratories, standard samples SY-2 and SY-3 and two internal standards were included with each sample batch. Analytical uncertainties are estimated to be about ±20% at worst, except near the detection limit for each element, where the uncertainty is much larger. Uncertainties for elements analyzed at the Regional XRF Facility are estimated to be about ±10% (K. Cameron, written communication, 1984).

Analyses for rare earth elements (Table 6) were done by neutron activation by J. Loop at the University of Ottawa, using methods described and referenced by Barr and Pride (1986). The accuracy and precision of the data are estimated to be ± 5%, except ± 10% for Lu and Tb.

MINERAL ANALYSES

Mineral analyses were done on polished thin sections by electron microprobe (Cambridge Instruments Microscan 5) at Dalhousie University, Halifax and at the Grant Institute of Geology, University of Edinburgh, Scotland.

MAPS
NOT
FILMED

CARTES
OMISES